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Installation and Operation of Particle Transport Simulation Programs to Model the Detection and Measurement of Space Radiation by Space-Borne Sensors

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13. ABSTRACT (Maximum 200 words)

This document is a report of the technical progress made during the period 10 Aug. 1999 - 31 July 2000 in the areas of: (1) research and evaluation of particle transport simulation programs for modeling the detection and measurement of space radiation byt space-borne sensors; (2) construction of realistic flight sensor computer models; (3) performance of particle transport calculations; (4) analysis of transport simulation results, including single particle tracking; (5) transfer and facilitation in the implementation of particle transport simulation technology to AFRL. Several computer programs (LAHET, ACCEPT, CYLTRAN, MCNPX) for particle transport simulation were applied to the modeling of the CEASE and HEP sensors. In addition, a preliminary version of a post-processor program for analysis of single particle histories from MCNPX was written. Shown in this report are several listings of input files, with geometry/materials drawings, for the various simulation programs, an example of (excerpt from) a track file analysis, and partial listings of code outputs.

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1. Introduction

The effort to be described in this report was performed as partial fulfillment of two primary objectives: (1) perform computer simulations of charged particle transport, energy and charge deposition in satellite-borne instrumentation used in research efforts of the Air Force Research Laboratory/ Space Weather Center of Excellence (AFRL/VSBXR) to detect and characterize (by type, energy, intensity, *etc.*) particles associated with ionizing radiation in space; and (2) transfer this simulation capability to AFRL/VSBXR and provide advice to Air Force researchers on its use. These simulations provide valuable assistance to scientists and engineers in the design and evaluation of on-board radiation measurement instrumentation.

During this reporting period we worked with the Monte Carlo simulation programs listed below at ARCON, and with the exception of the first, recommended installation of these programs and provided assistance and guidance for their use at AFRL. The Monte Carlo transport simulations programs that were used in the effort are:

- "LCS – The LAHET Code System" [1] - Transport code for protons, neutrons, mesons, deuterons, tritons, ^{3}He, alpha, photons
- "ITS 3.0 – Integrated TIGER Series of Coupled Electron/Photon Monte Carlo Code System" [2]
  a) TIGER – One-dimensional (slab geometry) multilayer code
  b) CYLTRAN – Cylindrical (axisymmetric) geometry code
  c) ACCEPT – General three-dimensional transport code
- "MCNPX, Version 2.1.5 – Monte Carlo transport code for neutrons, photons, electrons, mesons, protons, deuterons, tritons, ^{3}He, alpha" [3]

All but two of these codes utilize three-dimensional models of the transport medium, *i.e.* particle telescope or particle detection instrument. The exceptions are CYLTRAN, which applies only to 3-D models of cylindrically symmetric objects and TIGER, which is applicable only to simple multiplayer 1-D slab geometry.

MCNPX, Version 2.1.5, the most recent version of the Los Alamos Monte Carlo program MCNP[4] came into existence in November, 1999. The capabilities of this program far exceed those of LAHET and ITS. It has proven to be an excellent tool for transporting protons, electrons, neutrons and photons in the Compact Environmental Anomaly Sensor (CEASE)[5] and High Energy Proton (HEP)[6] sensor.

The visual editor program, MCNP-VISED[7], an adjunct to the MCNP codes, provides the capability to create and visualize MCNP geometry description files. MCNP-VISED was acquired and used primarily to display the geometry files that were created for CEASE and HEP. It has proven to be a valuable addition to the library of programs selected for this project, particularly as a tool for detecting errors in geometry model files.

In the following sections, we briefly discuss the computer programs listed above, some of their interrelationships, and provide descriptions and examples of our application of these codes to the modeling of particle transport and trajectory tracking in the CEASE and HEP instruments.

2. Monte Carlo Simulation Programs

2.1 LCS – The LAHET Code System [1]

At the outset of this effort, the LAHET Code System was used to model proton transport in the CEASE instrument. LAHET is a Monte Carlo code for the transport of nucleons, pions, and muons, and is based on the CALOR95/HETC [8] code that was originally developed at Oak Ridge National Laboratory. LAHET has a significant advantage over its predecessor, HETC, in that it uses the same problem geometry description method as that used in an early version of the LANL neutron-photon Monte Carlo code MCNP [4]. We have found that the MCNP outperforms any other simulation code with respect to geometry description. LAHET allows the user to choose between two intranuclear cascade models to describe the physics of nuclear interactions, the Bertini model (used in HETC) and the ISABEL [1] model which allows hydrogen, helium ions and antiprotons as projectiles and uses the Fermi breakup model for the breakup of light nuclei instead of the evaporation model incorporated in the Bertini model. The LCS-LAHET code system also provides a post-transport code (HTAPE [1]) for the analysis of the particle history file written by LAHET. This program has a large number of analysis options that allow the user to perform audits for energy deposition, mass and energy balance, particle conservation, surface fluxes and currents, and internal neutron fluxes. LAHET simulations of proton transport and trajectory tracking were performed during the past year for both the CEASE and HEP instruments.

2.2 The ITS 3.0 Code System [2]

The major portion of our modeling work for electron transport in the CEASE and HEP sensors was performed with the Integrated TIGER series of Coupled Electron/Photon Monte Carlo codes, a set of programs that efficiently solves electron/photon transport problems. These programs contain detailed physical models for electron and photon scattering and transport, secondary electron production, bremsstrahlung production, straggling and knock-on electron production. Some of these physical options can be "switched on or off" to isolate these effects and estimate their significance. For the purposes of modeling electron transport in CEASE and HEP, we found that two of the three ITS codes to be of use, CYLTRAN[2b] and ACCEPT[2c]. CYLTRAN, in some cases, could be used for HEP, while ACCEPT, the more general three-dimensional code, was applied to HEP and CEASE. Taking advantage of cylindrical symmetry, such as may be the case for instrument engineering models, CYLTRAN runs much more quickly than ACCEPT for the same problem. However, for full adherence to realistic situations, *i.e.* full production (flight) versions of these sensors, the use of ACCEPT is preferable.

2.3 MCNPX, Ver. 2.1.5 [3]

In March 1999, we acquired and installed the MCNP4B2[4] and MCNPX codes at ARCON. MCNPX incorporates all of the advantages of the Los Alamos MCNP code system, such as problem geometry specification and code documentation, while permitting transport of 34 particle types (including antiparticles). In order to make effective use of MCNPX, considerable experimentation with various input data types and geometry models was required. We found it necessary to rewrite the geometry, materials and source specifications for the CEASE and HEP input files, since several incompatibilities were found to exist between the formats required for this later version of MCNP (MCNP4B2 and MCNPX) and the earlier MCNP, Ver. 3 used in LAHET. After the initial "break-in" period, we concluded that MCNPX is the best overall program to be used for analysis of particle transport in space-borne sensors such as CEASE and

HEP. The obvious advantage to having one code that "does it all" is that only one geometry/material specification file is required for all particle transport problems. Furthermore, MCNP provides what is, in our opinion, the best geometry modeling capability of any of the available transport codes. We did find one disadvantage, however. The electron transport run times are much longer than their ITS counterparts, so that if computational effort and/or turn-around time become significant issues, use of ITS is preferable.

The three computer program collections, LCS-LAHET, ITS and MCNPX were not developed completely independently from one another and, in fact, share common "ancestry". The choice of MCNPX for most of our particle transport work is based on our opinion that MCNPX combines the best features of its predecessor codes: 1) the coupled electron/photon physics of ITS; 2) the proton transport and nuclear interaction physics of LAHET; and 3) the photon and neutron transport physics, cross-section libraries and geometry description capability of MCNP.

2.3.1. MCNP-VISED – Visual Editor for MCNP Input Files [7]

In addition to the Monte Carlo programs, we acquired and installed the MCNP geometry model visualization and construction program, MCNP-VISED[7]. We found that this program was extremely useful for visualizing and checking the validity of existing geometry models. The program displays the model in any number of modes and orientations. With it we have the ability to display all or part of the model, with or without surface labels, and with or without cell labels. In the color picture mode, a unique color designation is assigned to each material used in the problem. This program also checks and finds most geometry modeling errors. Simple typographical errors in the geometry specification file are usually difficult to identify in the file, however they show up prominently on the screen.

3. Proton Transport Modeling – CEASE Telescope [5]

3.1 LAHET CEASE Simulations

The Compact Environmental Anomaly Sensor (CEASE) instrument (see Figure1) overall dimensions are 10 x 10 x 8.2 cm. Looking top-down, the package is divided into four quadrants containing: 1) the energetic particle telescope to measure proton energy spectra; 2)&3) dosimeters; 4)p-i-n diode for single event effects measurement. The entire instrument is enclosed by an Al cover with a hole in one top corner to allow for the telescope aperture. The telescope geometry is cylindrical, has a tungsten collimator with a 45° half-angle conical aperture covered by a 9 μm thick light blocking Al foil, and is surrounded by a copper cylindrical shield on the sides and back. Inside the telescope, coaxial with the telescope axis, are two cylindrical solid state detectors, one with 25 mm^2 area x 150 μm thickness and the other with 50 mm^2 area x 700 μm thickness.

Engineering drawings of CEASE were obtained from R. Redus, Amptek Corp. on 08/25/99 [5]. Using these drawings, we wrote a geometry/materials description file for the "bare" (without case) CEASE telescope for use with the LAHET Code[1]. The level of detail in the geometry/materials (10 materials, 116 surfaces, 124 cells) file is nearly the same as that supplied in the engineering drawings. After several rounds of test runs and corrections, it was determined that the geometry file was free of errors (undefined holes, overlapping cells, etc.). The surface and cell layout diagrams are shown in Figures 2 and 3, respectively.

The geometry/materials file was then expanded (10 materials, 149 surfaces, 173 cells) to include the instrument frame and case, consisting of circuit boards, corner bolts and aluminum cover. Including the frame and case allows the investigator to more closely emulate the energy-angle spectra of particles entering the telescope via paths other than through the aperture. An annotated listing of this file, which can be used as input to LAHET and MCNP (Versions 3.0 and later), is given in Appendix 1. Several LAHET runs were made for 300 MeV protons normally incident on the CEASE collimator-aperture. Energy deposition and mass-energy balance audits were run on the particle history file. This was accomplished using the LCS-HTAPE history audit program. A portion of the HTAPE output, an energy deposition audit for the 300 MeV proton source is given in Appendix 2. In addition to the HTAPE audit program, a program was written at ARCON that traces single history trajectories in the LAHET track file.

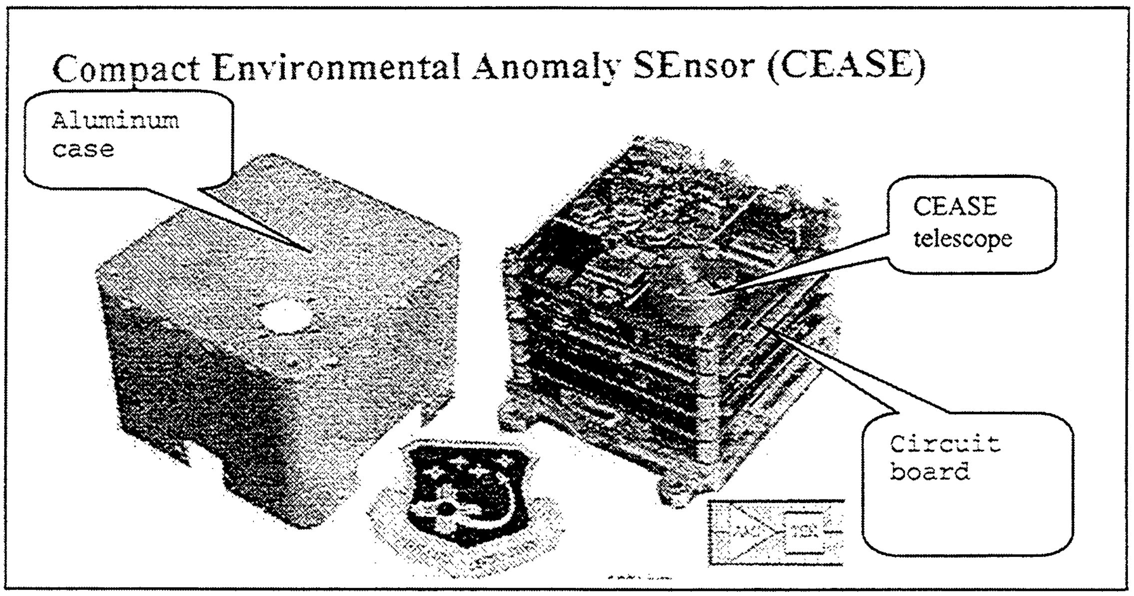

Figure 1. CEASE telescope [5,9] with case.

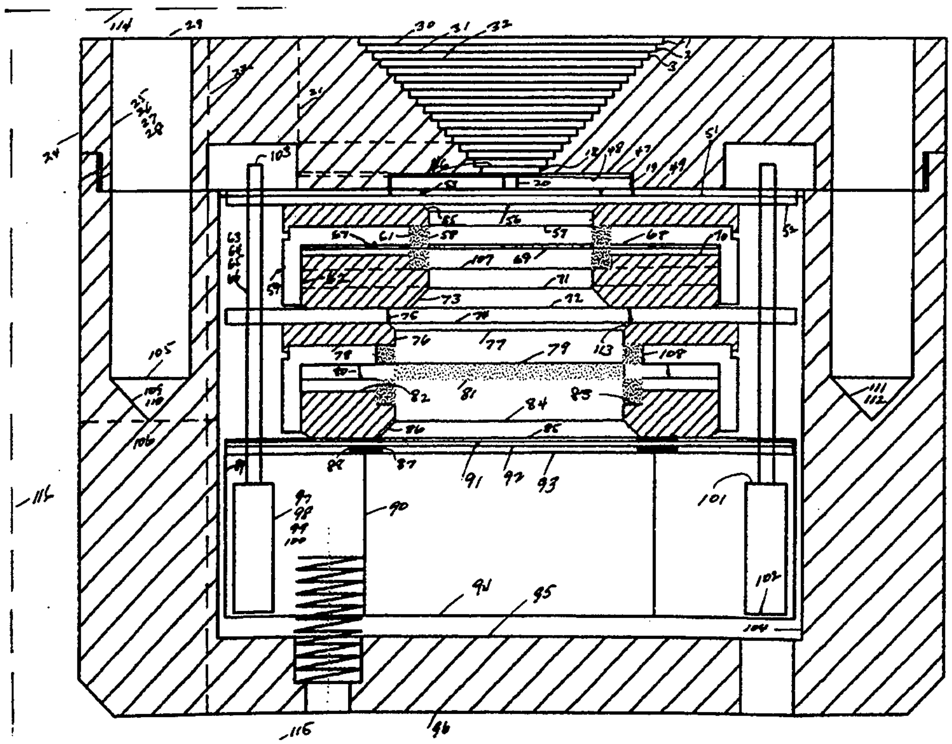

Figure 2. LAHET CEASE Telescope[9] Surface Layout (surface numbers refer to input file listed in Appendix 1).

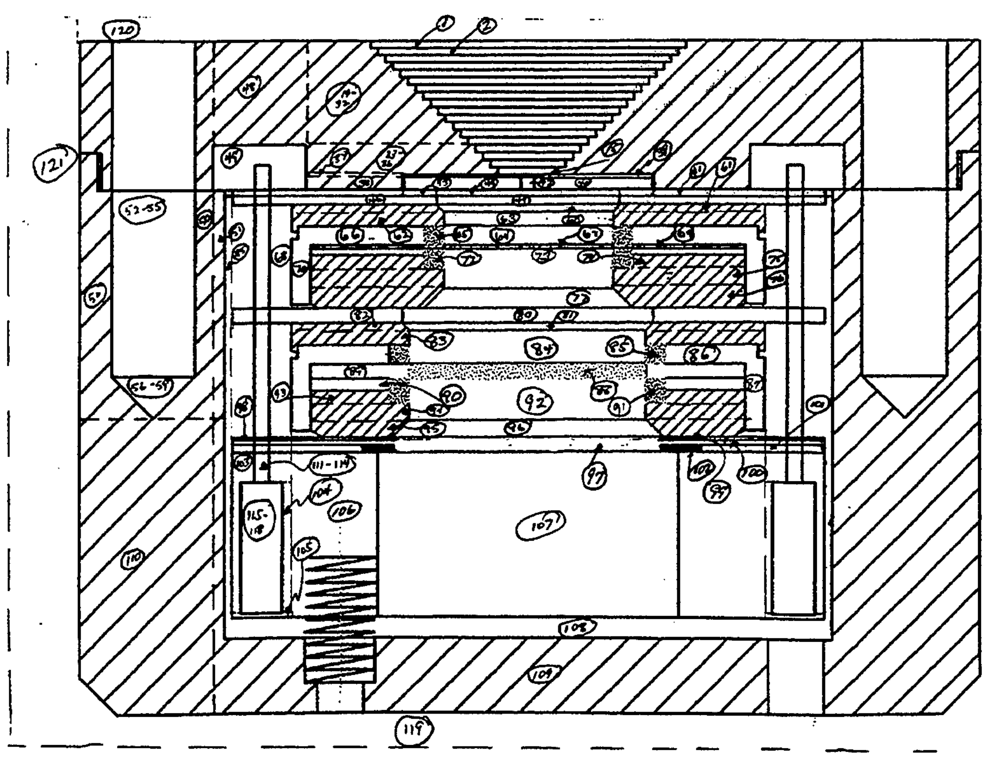

Figure 3. LAHET CEASE Telescope[9] Cell Layout (cell numbers refer to input file listed in Appendix 1).

3.2 MCNPX CEASE Simulations

With the arrival and installation of the MCNPX code in March of 1999, the effort was begun to perform the transport simulations for CEASE with MCNPX. An input file in the MCNPX format describing the geometry, including the frame and case, was written, and several test runs were made for both proton and electron sources. An input file describing a 300 MeV proton beam source entering with normal incidence through the CEASE telescope aperture is given in Appendix 3.

3.2.1 CEASE Geometry and Materials Specification

Partial diagrams of the cell and surface layouts for the CEASE telescope are shown in Figures 4, and 5, respectively. These diagrams were made using the MCNP-VISED visualization editor. The labels shown correspond to the 173 cells and 149 surfaces listed in the input file (Appendix 3). The material designations assigned to the cells can also be viewed with VISED utilizing color-coding. Nine materials were specified for this problem: brass, aluminum, tungsten, gold, stainless steel, conductive silicone elastomer (rubber), PMMA, silicon and copper. The exact material composition of the circuit board material is not readily attainable. However, it is known to be a mixture of fiberglass bound with epoxy resins. The high SiO_2 content and the material density closely approximating that of aluminum provide justification to assume that the circuit board material is aluminum for the purposes of our particle transport simulations. A color-coded material diagram for the telescope is shown in Figure 6.

Visualizations of the CEASE telescope geometry such as shown in Figures 4, 5 and 6, in addition to providing an effective debugging aid for problem geometry specifications, can provide a useful tool for following individual particle trajectories if augmented with coordinate axes and length units.

3.2.2 Selection of Particles for Transport Simulation ("mode" record)

Referring again to the MCNPX-CEASE input file (Appendix 3), the "mode" record (immediately following the list of surfaces) is the means by which the user selects that particles to be transported. In this calculation five particle types were selected, protons(h), neutrons(n), μ^- (|), photons(p), π^-(/). As is indicated in the source definition (SDEF) record, 300 MeV protons were assumed for the source particle (code is "par=9").

3.2.3 Output Tally Options

For the input run file (Appendix 3) shown, the output tally options chosen are a small subset of the large number available. These included energy deposition classified by particle type: for example, photon energy deposition [heating] tallies are F46:p, ... F86:p; proton energy deposition tallies are +F6:h, ... +F106:h); charge deposition (+F58:h,....+F98:h); proton number flux (F44:h,...F84:h); proton energy flux (*F94:h,.... *F134:h); and neutron number flux (F144:n,....F184:n). The integer arrays on the "F" tally records signify the cell numbers for which these tallies are to be made. An output option that is available, but was not chosen for the run shown is the calculation of pulse-height spectra for individual cells and the total for the entire geometry. Runs were made with both proton and electron sources for some of the cases that were run with the earlier codes, LAHET and ITS. As would be expected, the energy and charge deposition results obtained with MCNPX were not numerically identical with those previously obtained with the other codes, but did compare closely and for practical purposes could be regarded as equivalent.

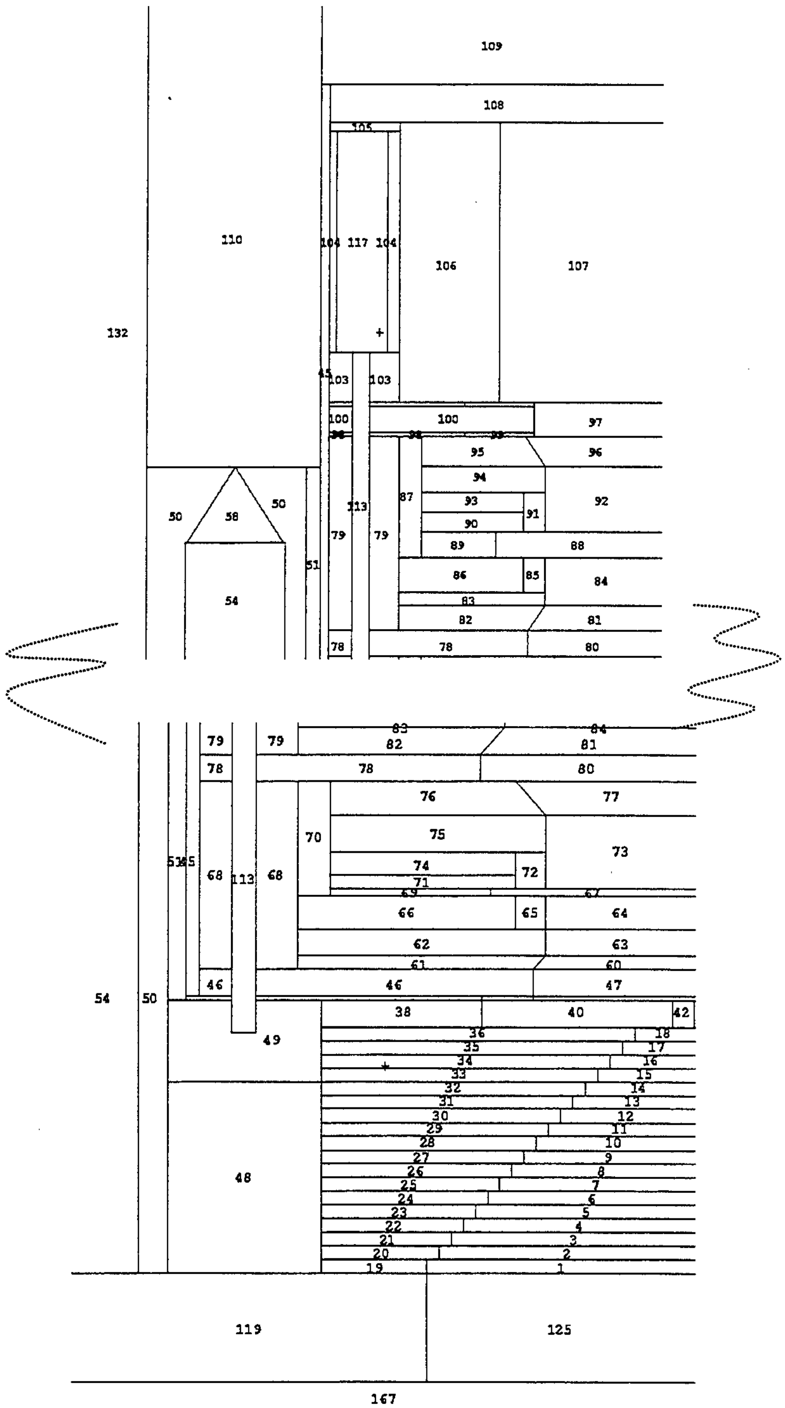

Figure 4. MCNPX Cell layout (partial) for CEASE [5,9] telescope (cell numbers refer to input file listed in Appendix 3). Drawings made with MCNP-VISED[7] editor.

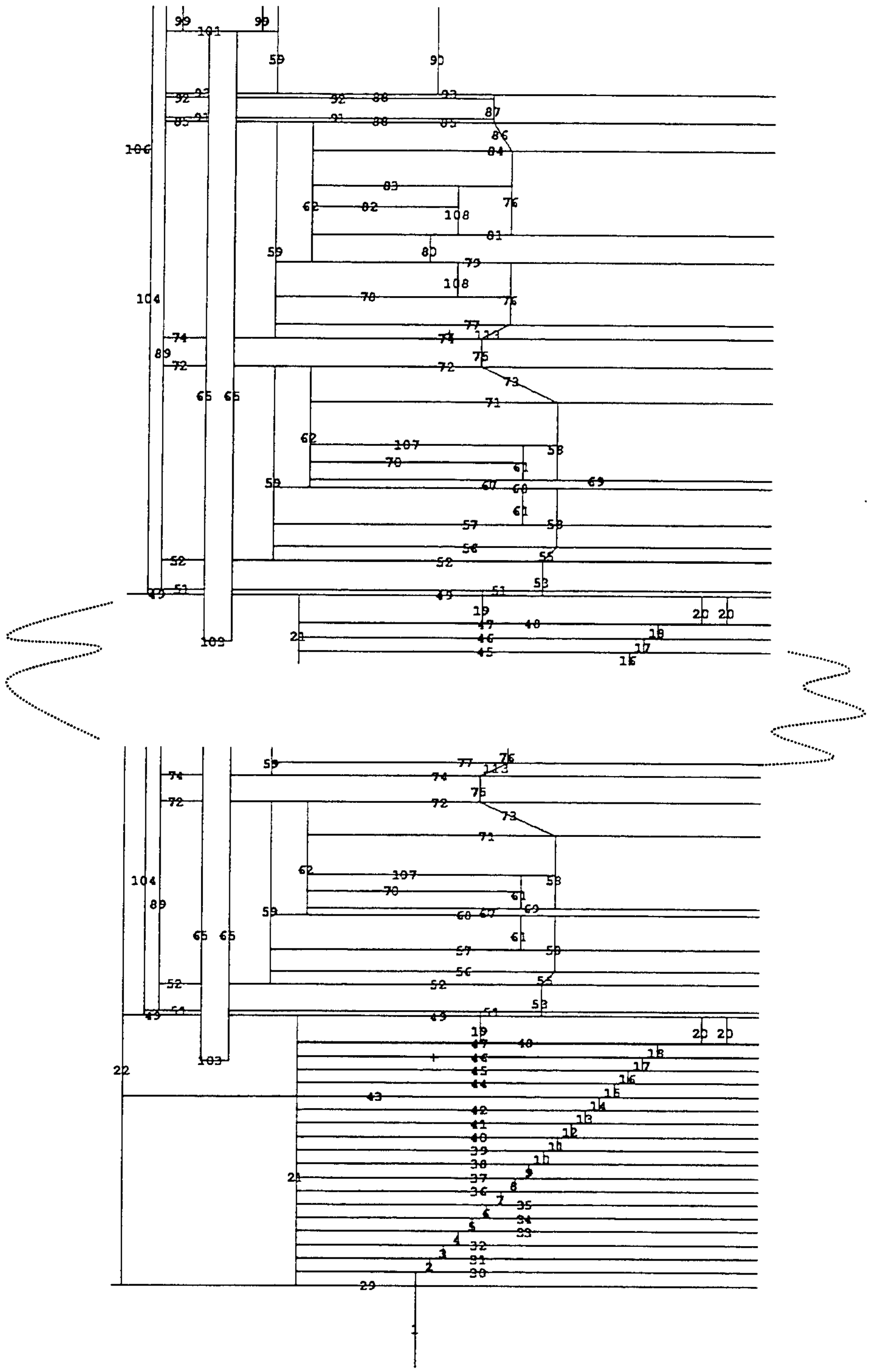

Figure 5. MCNPX Surface layout (partial) for CEASE[5,9] telescope (surface numbers refer to input file listed in Appendix 3). Drawings made with MCNP-VISED[7] editor.

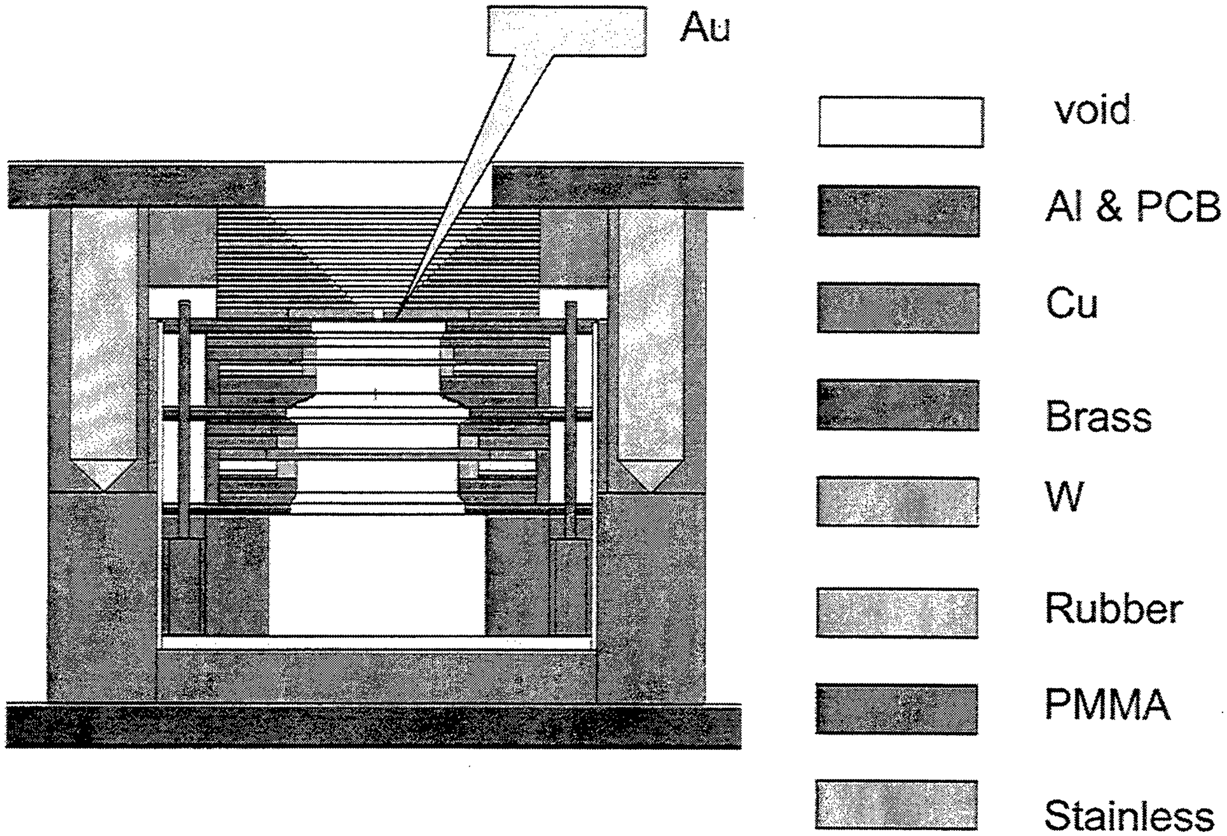

Figure 6. MCNPX Color-coded Materials Diagram for CEASE [5,9] telescope (color codes refer to input file listed in Appendix 3). Drawing made with MCNP-VISED[7] editor.

3.2.4. Particle Trajectory Analysis

Of particular importance to the AFRL/VSBXR space-borne sensor modeling effort is the ability to follow and analyze simulated individual particle tracks. The "ptrac" option in MCNPX provides this capability. The last record (`ptrac write=all file=asc`) in the input file causes MCNPX to write an ASCII format track file that records every event (scatter, absorption, surface crossing, escape, nuclear interaction) that occurs in every particle trajectory.

The following five pages (Figure 7) contain an annotated partial listing of the "ptrac" file for a single 300 MeV source proton history for the CEASE telescope-frame-case geometry. The file is configured so that every two lines (one consisting of integers and one consisting of floating point numbers) comprise an "event record". The events may be plane crossings, nuclear interactions, particle escape, particle absorptions, births of secondary, tertiary, *etc.* particles, deposits and withdrawals from the particle "bank", or particle deaths (energy below problem cut-off).

Surface crossing proton Collimator cells copper 300 MeV

```
        26      1000
      3000         1        40         9       119         2         0
-0.73159E-01 0.54137E+00 -0.20320E+00 0.00000E+00 0.00000E+00 0.10000E+01 0.30000E+03 0.10000E+01 0.00000E+00
      3000         2        29         0         9        19         9         1
-0.73159E-01 0.54137E+00 0.00000E+00 0.88037E-03 0.13094E-02 0.10000E+01 0.29839E+03 0.10000E+01 0.10387E-02
      3000         3        30         0         9        20         9         2
-0.73137E-01 0.54141E+00 0.25400E-01 0.26236E-02 -0.13688E-02 0.10000E+01 0.29781E+03 0.10000E+01 0.11687E-02
      3000         4        31         0         9        21         9         3
-0.73070E-01 0.54137E+00 0.50800E-01 0.19852E-02 0.61332E-02 0.99998E+00 0.29730E+03 0.10000E+01 0.12989E-02
      3000         5        32         0         9        22         9         4
-0.73019E-01 0.54153E+00 0.76200E-01 -0.53905E-02 0.79414E-02 0.99995E+00 0.29679E+03 0.10000E+01 0.14291E-02
      3000         6        33         0         9        23         9         5
-0.73156E-01 0.54173E+00 0.10160E+00 -0.38863E-02 0.39406E-02 0.99998E+00 0.29627E+03 0.10000E+01 0.15594E-02
      3000         7        34         0         9        24         9         6
-0.73255E-01 0.54183E+00 0.12700E+00 -0.90732E-02 -0.20110E-02 0.99996E+00 0.29572E+03 0.10000E+01 0.16898E-02
      3000         8        35         0         9        25         9         7
-0.73486E-01 0.54178E+00 0.15240E+00 -0.72679E-02 0.71319E-03 0.99997E+00 0.29517E+03 0.10000E+01 0.18202E-02
```

X Y Z U V W E wt Time

```
      3000         9        36         0         9        26         9         8
-0.73670E-01 0.54180E+00 0.17780E+00 -0.34775E-02 -0.14172E-02 0.99999E+00 0.29461E+03 0.10000E+01 0.19507E-02
      3000        10        37         0         9        27         9         9
-0.73758E-01 0.54176E+00 0.20320E+00 -0.46520E-02 -0.53498E-02 0.99997E+00 0.29410E+03 0.10000E+01 0.20813E-02
      3000        11        38         0         9        28         9        10
-0.73877E-01 0.54162E+00 0.22860E+00 -0.41022E-02 -0.37712E-03 0.99999E+00 0.29357E+03 0.10000E+01 0.22120E-02
      3000        12        39         0         9        29         9        11
-0.73981E-01 0.54161E+00 0.25400E+00 -0.67750E-02 -0.30934E-02 0.99997E+00 0.29300E+03 0.10000E+01 0.23428E-02
      3000        13        40         0         9        30         9        12
-0.74153E-01 0.54154E+00 0.27940E+00 -0.10300E-01 -0.58924E-02 0.99993E+00 0.29244E+03 0.10000E+01 0.24736E-02
      3000        14        41         0         9        31         9        13
-0.74415E-01 0.54139E+00 0.30480E+00 -0.74642E-02 -0.59519E-02 0.99995E+00 0.29188E+03 0.10000E+01 0.26046E-02
      3000        15        42         0         9        32         9        14
-0.74604E-01 0.54124E+00 0.33020E+00 -0.92859E-02 -0.29078E-02 0.99995E+00 0.29131E+03 0.10000E+01 0.27356E-02
      3000        16        43         0         9        33         9        15
-0.74840E-01 0.54116E+00 0.35560E+00 -0.10694E-01 -0.50254E-02 0.99993E+00 0.29077E+03 0.10000E+01 0.28667E-02
      3000        17        44         0         9        34         9        16
-0.75112E-01 0.54103E+00 0.38100E+00 -0.11878E-01 -0.90684E-02 0.99989E+00 0.29021E+03 0.10000E+01 0.29979E-02
      3000        18        45         0         9        35         9        17
-0.75413E-01 0.54080E+00 0.40640E+00 -0.72596E-02 -0.36675E-02 0.99997E+00 0.28969E+03 0.10000E+01 0.31291E-02
      3000        19        46         0         9        36         9        18
-0.75598E-01 0.54071E+00 0.43180E+00 -0.75681E-02 -0.13297E-01 0.99988E+00 0.28912E+03 0.10000E+01 0.32605E-02
      3000        20        47         0         9        37         9        19
-0.75790E-01 0.54037E+00 0.45720E+00 -0.11359E-01 -0.13023E-01 0.99985E+00 0.28857E+03 0.10000E+01 0.33919E-02
      3000        21        48         1         9        38         9        20
-0.75800E-01 0.54036E+00 0.45810E+00 -0.11897E-01 -0.13749E-01 0.99983E+00 0.28855E+03 0.10000E+01 0.33966E-02
```

Figure 7. PTRAC file example (annnotated)

void

Al

Brass

PMMA

Si

```
     3000        22        49         0         9        41         0        21
-0.76394E-01  0.53967E+00  0.50800E+00 -0.11628E-01 -0.12597E-01  0.99985E+00  0.28753E+0            )E+01  0.36550E-02
     3000        23        51         0         9        46         2        22
-0.76493E-01  0.53957E+00  0.51652E+00 -0.11628E-01 -0.12597E-01  0.99985E+00  0.28753E+03  0.10000E+01  0.36991E-02
     3000        24        52         0         9        61         1        23
-0.77084E-01  0.53893E+00  0.56732E+00 -0.13351E-01 -0.86086E-02  0.99987E+00               0.10000E+01  0.39625E-02
     3000        25        56         0         9        62         1        24
-0.77416E-01  0.53871E+00  0.59221E+00 -0.12698E-01 -0.78256E-02  0.99989E+00               0.10000E+01  0.40916E-02
     3000        26        57         0         9        66         7        25
-0.77924E-01  0.53840E+00  0.63218E+00 -0.15496E-01 -0.23480E-02  0.99988E+00  0.2858       0.10000E+01  0.42990E-02
     3000        27        68         0         9        69         8        26
-0.78927E-01  0.53825E+00  0.69690E+00 -0.15013E-01 -0.27882E-02  0.99988E+00  0.28555E+03  0.10000E+01  0.46352E-02
     3000        28        69         0         9        71         0        27
-0.79113E-01  0.53821E+00  0.70930E+00 -0.14830E-01 -0.29790E-02  0.99989E+00  0.28547E+03  0.10000E+01  0.46996E-02
     3000        29        70         0         9        74         1        28
-0.79591E-01  0.53812E+00  0.74150E+00 -0.14830E-01 -0.29790E-02  0.99989E+00  0.28547E+03  0.10000E+01  0.48669E-02
     3000        30       107         1         9        75         1        29
-0.80037E-01  0.53803E+00  0.77160E+00 -0.18750E-01 -0.40594E-02  0.99982E+00  0.28486E+03  0.10000E+01  0.50234E-02
     5000        31        71         1         9        76         1        30
-0.81436E-01  0.53772E+00  0.84620E+00 -0.24095E-01  0.53021E-02  0.99970E+00  0.28328E+03  0.10000E+01  0.54113E-02
     2033        31        13         1         9        76         1        31
-0.82689E-01  0.53         0.89817E+00 -0.23586E-01 -0.58246E-03  0.99972E+00  0.28216E+03  0.10000E+01  0.56821E-02
```

Proton goes into bank

Neutron #1

```
    4000        42         0         0         1        76         1        31
-0.82689E-01  0.53800E+00  0.89817E+00 -0.73917E-01 -0.4   5E+00 -0.90615E+00  0.26093E+00  0.10000E+01  0.56821E-03
     3000        42     28000       -99         1        76         1        32
-0.82970E-01  0.53642E+00  0.89472E+00 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.11071E-02
     3000        43        72        67         1        78         2        32
-0.89699E-01  0.56796E+00  0.90840E+00 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.62152E-02
     3000        44        74        67         1        82         1        32
-0.11419E+00  0.68278E+00  0.95820E+00 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.24809E-01
     3000        45        77        67         1        83         1        32
-0.12644E+00  0.74019E+00  0.98310E+00 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.34106E-01
     3000        46        59        23         1        79         0        32
-0.13669E+00  0.78824E+00  0.10039E+01 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.41886E-01
     3000        47        89        23         1        45         0        32
-0.17880E+00  0.98569E+00  0.10896E+01 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.73861E-01
     3000        48       104        23         1        51         9        32
 •
 •
     3000        55       127        67         1       134         0        32
-0.12641E+01  0.60736E+01  0.32963E+01 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.89777E+00
     3000        56       123        25         1       124         2        32
-0.15506E+01  0.74168E+01  0.38789E+01 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.11153E+01
     5000        57       124        25         1       172         0        32
-0.15940E+01  0.76200E+01  0.39670E+01 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.11482E+01
     2033        57         1         2         1       172         0        32
-0.15940E+01  0.76200E+01  0.39670E+01 -0.19205E+00  0.90035E+00  0.39050E+00  0.24599E+00  0.99845E+00  0.11482E+01
```

Figure 7. PTRAC file example (cont.)

```
                                                    Neutron #2
     3000        41         0          0          1                                31
  -0.82689E-01  0.53800E+00  0.89817E+00 -0.44065E+00 -0.[illegible]41E-01 -0.89692E+00  0.70746E+00  0.10000E+01  0.56821E-03
     3000        42        71        153          1          75           1        31
  -0.10822E+00  0.53586E+00  0.84620E+00 -0.44065E+00 -0.36941E-01 -0.89692E+00  0.70746E+00  0.10000E+01  0.55515E-02
     3000        43       107        153          1          74           1        31
  -0.14487E+00  0.53279E+00  0.77160E+00 -0.44065E+00 -0.36941E-01 -0.89692E+00  0.70746E+00  0.10000E+01  0.12705E-01
     3000        44        70        153          1          71           0        31
•
•
•
                                                    Gamma #1
     5000        72       114        153          1                                31
  -0.62379E+00  0.49264E+00 -0.20320E+00 -0.44065E+00 -0.[illegible]      [illegible]2E+00  0.70746E+00  0.10000E+01  0.10618E+00
     2033        72         1          3          1          [illegible]  0        31
  -0.62379E+00  0.49264E+00 -0.20320E+00 -0.44065E+00 -0.[illegible]6941E-01 -0.89692E+00  0.70746E+00  0.10000E+01  0.10618E+00
     4000        40         0          0          2          76           1        31
  -0.82689E-01  0.53800E+00  0.89817E+00  0.27157E+00 -0.53532E+00 -0.79980E+00  0.24890E-01  0.10000E+01  0.10281E+12
                                                                 Gamma #2
     5000        40     40000          3          2          76
  -0.78306E-01  0.52936E+00  0.88526E+00  0.27157E+00 -0.53532E+00 [illegible]  [illegible]890E-01  0.10000E+01  0.10281E+12
     2033        40        12          4          2          76
  -0.78306E-01  0.52936E+00  0.88526E+00  0.27157E+00 -0.[illegible]532E+00 -0.79980E+00  0.24890E-01  0.10000E+01  0.10281E+12
     4000        39         0          0          2          76           1        31
  -0.82689E-01  0.53800E+00  0.89817E+00 -0.99950E+00  0.31429E-01 -0.31231E-02  0.28110E-01  0.10000E+01  0.77411E+03
     4000        39     39000          3          2          76           1        32
  -0.85178E-01  0.53808E+00  0.89816E+00 -0.58213E+00  0.80996E+00  0.71308E-01  0.89070E-02  0.10000E+01  0.77411E+03
                                                               Gamma #3
     5000        39     39000          3          2          76           1        33
  -0.85557E-01  0.53861E+00  0.89821E+00 -0.58213E+00  0.80996E+[illegible]  [illegible]  0.89070E-02  0.10000E+01  0.77411E+03
     2033        39        12          5          2          76          [illegible]  [illegible]
  -0.85557E-01  0.53861E+00  0.89821E+00 -0.58213E+00 [illegible]996E+00 [illegible]71308E-01  0.89070E-02  0.10000E+01  0.77411E+03
     3000        38         0          0          2          76           1        31
  -0.82689E-01  0.53800E+00  0.89817E+00  0.58309E+00  0.68409E+00 -0.43821E+00  0.31260E+00  0.10000E+01  0.59727E-03
     3000        39        71        115          2          75           1        31
  -0.13538E-01  0.61913E+00  0.84620E+00  0.58309E+00  0.68409E+00 -0.43821E+00  0.31260E+00  0.10000E+01  0.99285E-03
     3000        40        62         41          2          70           7        31
   0.80763E-01  0.72976E+00  0.77533E+00  0.58309E+00  0.68409E+00 -0.43821E+00  0.31260E+00  0.10000E+01  0.15323E-02
     3000        41        59         39          2          68           0        31
   0.13137E+00  0.78914E+00  0.73730E+00  0.58309E+00  0.68409E+00 -0.43821E+00  0.31260E+00  0.10000E+01  0.18218E-02
     3000        42        89         34          2          45           0        31
   0.27887E+00  0.96218E+00  0.62645E+00  0.58309E+00  0.68409E+00 -0.43821E+00  0.31260E+00  0.10000E+01  0.26656E-02
     3000        43       104         34          2          51           9        31
   0.29697E+00  0.98343E+00  0.61284E+00  0.58309E+00  0.68409E+00 -0.43821E+00  0.31260E+00  0.10000E+01  0.27692E-02
     4000        44        22         33          2          50           9        31
   0.32485E+00  0.10161E+01  0.59189E+00  0.58309E+00  0.68409E+00 -0.43821E+00  0.31260E+00  0.10000E+01  0.29287E-02
     4000        44     44000          1          2          50           9        32
   0.53994E+00  0.12685E+01  0.43024E+00 -0.81208E-01  0.35994E-01  0.99605E+00  0.16517E+00  0.10000E+01  0.41591E-02
     4000        44     44000          1          2          50           9        33
   0.53735E+00  0.12696E+01  0.46202E+00 -0.67508E+00 -0.46651E+00  0.57153E+00  0.14656E+00  0.10000E+01  0.42655E-02
     5000        44     44000          3          2          50           9        34
   0.33551E+00  0.11301E+01  0.63291E+00 -0.67508E+00 -0.46651E[illegible]  [illegible]  0.14656E+00  0.10000E+01  0.52629E-02
                                                              Gamma #4
     2033        44        12          6          2          50          [illegible]  34
   0.33551E+00  0.11301E+01  0.63291E+00 -0.67508E+00 -0.[illegible]  [illegible]0  0.14656E+00  0.10000E+01  0.52629E-02
     3000        37         0          0          2          76           1        31
  -0.82689E-01  0.53800E+00  0.89817E+00  0.41373E-01  0.11914E+00 -0.99201E+00  0.67440E+00  0.10000E+01  0.57797E-03
```

Figure 7. PTRAC file example (cont.)

```
     3000         38         71        172          2         75          1         31
 -0.80521E-01  0.54424E+00  0.84620E+00  0.41373E-01  0.11914E+00 -0.99201E+00  0.67440E+00  0.10000E+01  0.75272E-03
     3000         39        107        172          2         74          1         31
 -0.77410E-01  0.55320E+00  0.77160E+00  0.41373E-01  0.11914E+00 -0.99201E+00  0.67440E+00  0.10000E+01  0.10036E-02
     3000         40         70        172          2         71          0         31
•
•
•
•

     3000         41        104         31          2         51          9         31
  0.94604E+00  0.40042E+00  0.10435E+01  0.98160E+00 -0.13128E+00  0.13863E+00  0.27751E+01  0.10000E+01  0.40640E-02
     3000         42         22         30          2         50          9         31
  0.99123E+00  0.39438E+00  0.10498E+01  0.98160E+00 -0.13128E+00  0.13863E+00  0.27751E+01  0.10000E+01  0.42175E-02
     3000         43         24         21          2        132          0         31
  0.14883E+01  0.32790E+00  0.11200E+01  0.98160E+00 -0.13128E+00  0.13863E+00  0.27751E+01  0.10000E+01  0.59067E-02
     3000         44        119         11          2        122          2         31
  0.74168E+01 -0.46496E+00  0.19573E+01  0.98160E+00 -0.13128E+00  0.13863E+00  0.27751E+01  0.10000E+01  0.26053E-01
     5000         45        120         11          2        170          0         31
  0.76200E+01 -0.49214E+00  0.19860E+01  0.98160E+00 -0.13128E+00  0.13863E+00  0.27751E+01  0.10000E+01  0.26743E-01
     2033         45          1          9          2        170          0         31
  0.76200E+01 -0.49214E+00  0.19860E+01  0.98160E+00 -0.13128E+00  0.13863E+00  0.27751E+01  0.10000E+01  0.26743E-01
•
•
•
•
```

Proton #2

```
     3000         32          0          0          9         76          1         31
 -0.82689E-01  0.53800E+00  0.89817E+00 -0.43040E+00 -0.81602E-01  0.89894E+00  0.16031E+03  0.10000E+01  0.56821E-03
     3000         33         72         26          9         78          2         32
 -0.87588E-01  0.53707E+00  0.90840E+00 -0.43106E+00 -0.80914E-01  0.89869E+00  0.15997E+03  0.10000E+01  0.64120E-03
     3000         34         74         26          9         82          1         33
 -0.11147E+00  0.53259E+00  0.95820E+00 -0.43337E+00 -0.84165E-01  0.89728E+00  0.15935E+03  0.10000E+01  0.99686E-03
     3000         35         77         25          9         83          1         34
 -0.12350E+00  0.53025E+00  0.98310E+00 -0.42434E+00 -0.93782E-01  0.90064E+00  0.15850E+03  0.10000E+01  0.11752E-02
     3000         36         78         25          9         86          7         35
 -0.14696E+00  0.52507E+00  0.10329E+01 -0.41348E+00 -0.10588E+00  0.90434E+00  0.15680E+03  0.10000E+01  0.15314E-02
     3000         37         79         25          9         89          8         36
 -0.17540E+00  0.51778E+00  0.10951E+01 -0.41643E+00 -0.11081E+00  0.90239E+00  0.15640E+03  0.10000E+01  0.19764E-02
     3000         38         81         25          9         90          0         37
 -0.19838E+00  0.51167E+00  0.11449E+01 -0.41898E+00 -0.11282E+00  0.90096E+00  0.15589E+03  0.10000E+01  0.23337E-02
     3000         39         82         25          9         93          1         38
 -0.22154E+00  0.50543E+00  0.11947E+01 -0.41898E+00 -0.11282E+00  0.90096E+00  0.15589E+03  0.10000E+01  0.26921E-02
     3000         40         83         25          9         94          1         39
 -0.23889E+00  0.50076E+00  0.12320E+01 -0.41836E+00 -0.99787E-01  0.90279E+00  0.15461E+03  0.10000E+01  0.29606E-02
     3000         41         84         25          9         95          1         41
 -0.26769E+00  0.49391E+00  0.12942E+01 -0.41642E+00 -0.98159E-01  0.90386E+00  0.15264E+03  0.10000E+01  0.34088E-02
     3000         42         85         25          9         99          4         42
 -0.29064E+00  0.48850E+00  0.13440E+01 -0.41955E+00 -0.87831E-01  0.90347E+00  0.15094E+03  0.10000E+01  0.37691E-02
     3000         43         91         24          9        100          2         43
```

Figure 7. PTRAC file example (cont.)

```
-0.29389E+00  0.48782E+00  0.13510E+01 -0.40530E+00 -0.82322E-01  0.91047E+00  0.15050E+03  0.10000E+01  0.38200E-02
      3000        44          92          24           9          102           4          44
-0.30951E+00  0.48464E+00  0.13861E+01 -0.41261E+00 -0.84240E-01  0.90700E+00  0.15002E+03  0.10000E+01  0.40734E-02
      3000        45          93          25           9          106           7          45
-0.31302E+00  0.48393E+00  0.13938E+01 -0.41697E+00 -0.88668E-01  0.90459E+00  0.14957E+03  0.10000E+01  0.41293E-02
      3000        46          94          25           9          108           0          46
-0.57110E+00  0.42905E+00  0.19537E+01 -0.41708E+00 -0.89338E-01  0.90447E+00  0.14563E+03  0.10000E+01  0.82093E-02
      3000        47          95          25           9          109           9          47
-0.59983E+00  0.42289E+00  0.20160E+01 -0.41708E+00 -0.89338E-01  0.90447E+00  0.14563E+03  0.10000E+01  0.86682E-02
      3000        48          96          26           9          126           2          53
-0.71318E+00  0.39022E+00  0.22650E+01 -0.42296E+00 -0.14669E+00  0.89420E+00  0.13660E+03  0.10000E+01  0.10523E-01
      3000        49         125          27           9          133           0          55
-0.80279E+00  0.35902E+00  0.24543E+01 -0.42742E+00 -0.15491E+00  0.89068E+00  0.13388E+03  0.10000E+01  0.11972E-01
      3000        50         126          27           9          127           2          56
-0.11307E+01  0.24018E+00  0.31375E+01 -0.42742E+00 -0.15491E+00  0.89068E+00  0.13388E+03  0.10000E+01  0.17260E-01
      3000        51         127          27           9          134           0          57
-0.12069E+01  0.21257E+00  0.32963E+01 -0.42924E+00 -0.16210E+00  0.88852E+00  0.13146E+03  0.10000E+01  0.18489E-01
      3000        52         128          27           9          128           2          58
-0.15369E+01  0.87924E-01  0.39795E+01 -0.42924E+00 -0.16210E+00  0.88852E+00  0.13146E+03  0.10000E+01  0.23829E-01
      3000        53         129          27           9          135           0          59
-0.16136E+01  0.58963E-01  0.41383E+01 -0.43537E+00 -0.15394E+00  0.88699E+00  0.12940E+03  0.10000E+01  0.25070E-01
      3000        54         130          27           9          129           2          60
-0.19490E+01 -0.59618[illegible]                                0  0.88699E+00  0.12940E+03  0.10000E+01  0.30455E-01
      3000        55                                                            0          62
-0.20269E+01 -0.87192[illegible]                                0  0.88843E+00  0.12707E+03  0.10000E+01  0.31707E-01
      3000        56                     115           9          121           2          63
-0.23368E+01 [illegible]E+00  0.56174E+01 -0.43215E+00 -0.15472E+00  0.88843E+00  0.12707E+03  0.10000E+01  0.36757E-01
      5000        57         117         115           9          169           0          66
-0.25400E+01 -0.26986E+00  0.60304E+01 -0.43722E+00 -0.17055E+00  0.88303E+00  0.12154E+03  0.10000E+01  0.40058E-01
      9000        57           1          12           9          169           0          66
-0.25400E+01 -0.26986E+00  0.60304E+01 -0.43722E+00 -0.17055E+00  0.88303E+00  0.12154E+03  0.10000E+01  0.40058E-01
```

Proton #2 escapes

End of history for this source particle

Figure 7. PTRAC file example (cont.)

The first cluster of event records shown in Figure 7 describes the incidence of a 300 MeV proton (particle type label 9) normally incident on the copper collimator of the CEASE telescope. Several surface crossings (event code 3000) of a 300 MeV proton occur as the proton penetrates the collimator cells. The proton cross surfaces 29, 30, 31, 32, *etc.*, into cells 19, 20, 21, 22, *etc.* As indicated in the next event record cluster, the second line of the record contains the (X,Y,Z) coordinates of the event (crossing) point, trajectory (or particle velocity) direction cosines (U,V,W), particle energy (E in MeV), particle statistical weight (wt) (arises when/if variance reduction techniques such as particle splitting and "Russian roulette" are used), and finally, the time (sec) of occurrence.

The annotations shown in the next cluster point out the material designation, the integers corresponding to the material ("M" records) code of the input file. At the end of this cluster the source proton undergoes a nuclear interaction in cell #76 (brass annulus mounting for detector DFT) and is deposited in the particle bank. A neutron is "born" at the same coordinate point and eventually escapes (event code 5000) out the case side (x-plane #124). A second neutron appears from the same nuclear interaction (cell #76) and eventually escapes through the top of the case (z-plane #114). The next block of event records shows the origination of four gammas. Their trajectories are followed to their eventual escapes. The final block of records shows the trajectory of a secondary proton, created in the nuclear interaction described above, that travels along a nearly straight track (the small magnitudes of the deflections are evident from the small changes in the track direction cosines) and then escapes through x-plane #117 of the case. The event code 9000 signifies the end of the source particle history.

We have written a program that reads and interprets "ptrac" files. This program will eventually be modified to edit the file for events of particular interest to researchers at AFRL.

The MCNPX input files containing the geometry models for the CEASE telescope with and without the frame and case are now ready to be used in research both at ARCON and at AFRL.

4. Proton Transport Modeling - HEP Flight Sensor[6]

4.1 MCNPX HEP[6] Simulations

A new MCNPX geometry input file for the in-flight version of the HEP instrument was created from a complete set of manufacturing drawings supplied by Amptek, Inc.[6b] The drawings were highly detailed, enabling construction of a realistic MCNPX model. A drawing of the engineering version of HEP[6a] had also been available to us from earlier work that we had performed on a contract with Amptek, Inc.[10]. An MCNPX geometry description was also made for the earlier version. This was done for the following three reasons:

1) since several investigations had already been performed earlier using other codes, such as HETC, LAHET, ACCEPT and CYLTRAN on the relatively simple engineering model geometry, sufficient data existed to validate MCNPX Monte Carlo results for the engineering model, which can then be used for a "sanity check" on MCNPX results obtained for the final manufactured version.
2) the engineering version geometry is simple and requires little effort to write the MCNPX file.
3) displaying the two HEP models together effectively illustrates the contrast in detail level required for the description of the two versions.

The two MCNPX models are shown in Figure 8, (engineering model, Figure 8(a): manufacturing model, Figure 8(b)).

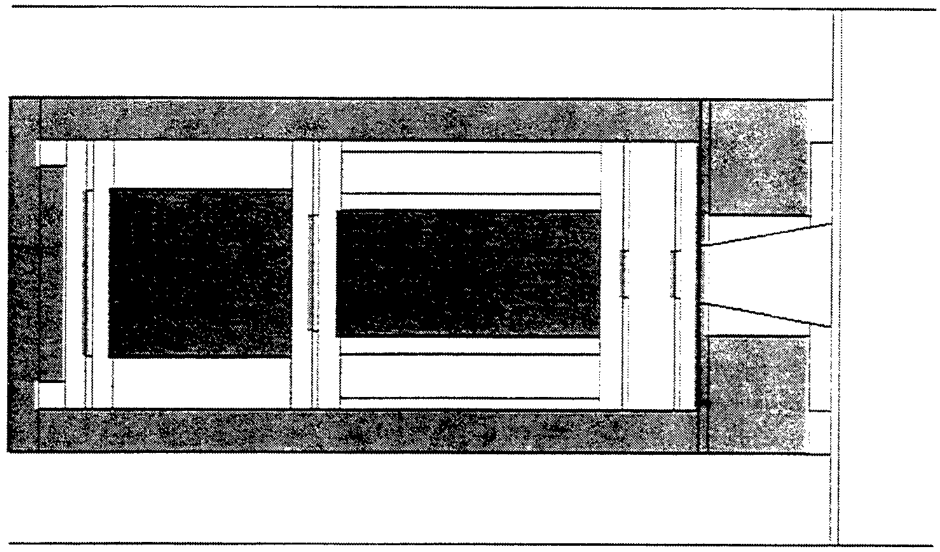

Figure 8(a). VISED rendering of MCNPX geometry/materials file for HEP flight sensor engineering model [6a].

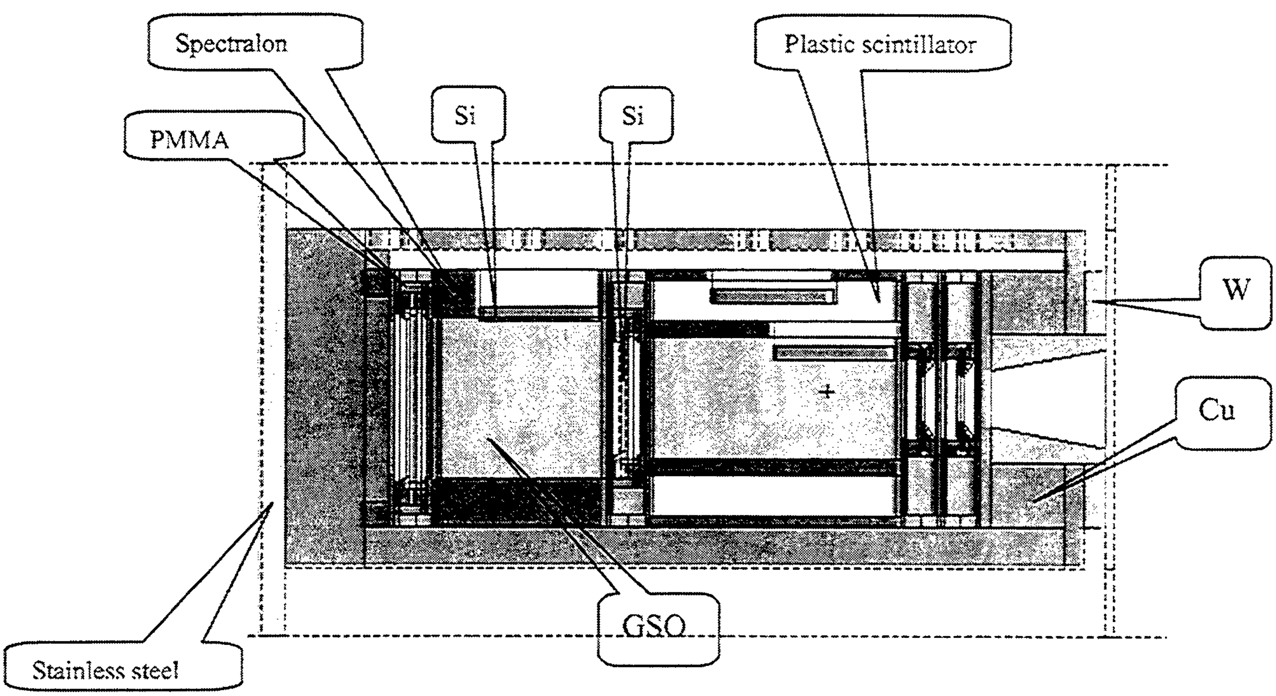

Figure 8(b). VISED rendering of MCNPX geometry/materials file for HEP flight sensor manufactured model [6b] (material color codes, differing from those shown in Figure 8(a), are automatically chosen by the VISED program)

The MCNPX input file corresponding to the HEP flight sensor depicted in Figure 8(b) is listed in Appendix 4. Several MCNPX runs were made to test the robustness of the geometry/materials file. The purpose was to uncover "holes" (errors) in the geometry specification. An efficient way to determine which, if any, cells are improperly defined in the input file is to run a large number of case histories for several source configurations and energies. Diagnostics appear in the MCNPX output when a particle has "lost its way". Armed with this information, we then used VISED to view the specific region of the geometry where the problem occurred, and made the appropriate corrections to the geometry records. The run file shown in Appendix 4 was used to simulate a 150 MeV proton disk source (3.0 cm radius) isotropically incident on a side of the aluminum case enclosing the sensor. For this and other diagnostic runs, we chose only to transport protons, as this would provide sufficient exercise of MCNPX to uncover geometry errors without unnecessary expenditure of computational effort.

Figures 9(a) and 9(b) are VISED partial views of the cell and surface structures, respectively, of the HEP flight sensor. The cell and surface numbers correspond to those given in the file listed in Appendix 4. While considerable detail is shown in these figures, the cell and surface label numbers are difficult, if not impossible, to decipher near the silicon wafer detectors. The model details of these areas can be more clearly viewed, as shown in the close-up cell drawings of silicon wafer detectors D3 (Figure 10) and D4 (Figure 11). Distinction between the electrically active and inactive areas of the silicon wafers is made by assignment of separate cells to the wafer portions. In detector D3, cell #77 represents the electrically active part, and cell #78 the inactive part. The corresponding cells for D4 are 102 and 103.

The MCNPX input files containing the geometry models for both the engineering and final versions of the HEP flight sensor will provide a useful research tool for AFRL and ARCON. We will assist in their implementation as well as provide guidance for model modification, where necessary, in the AFRL research effort.

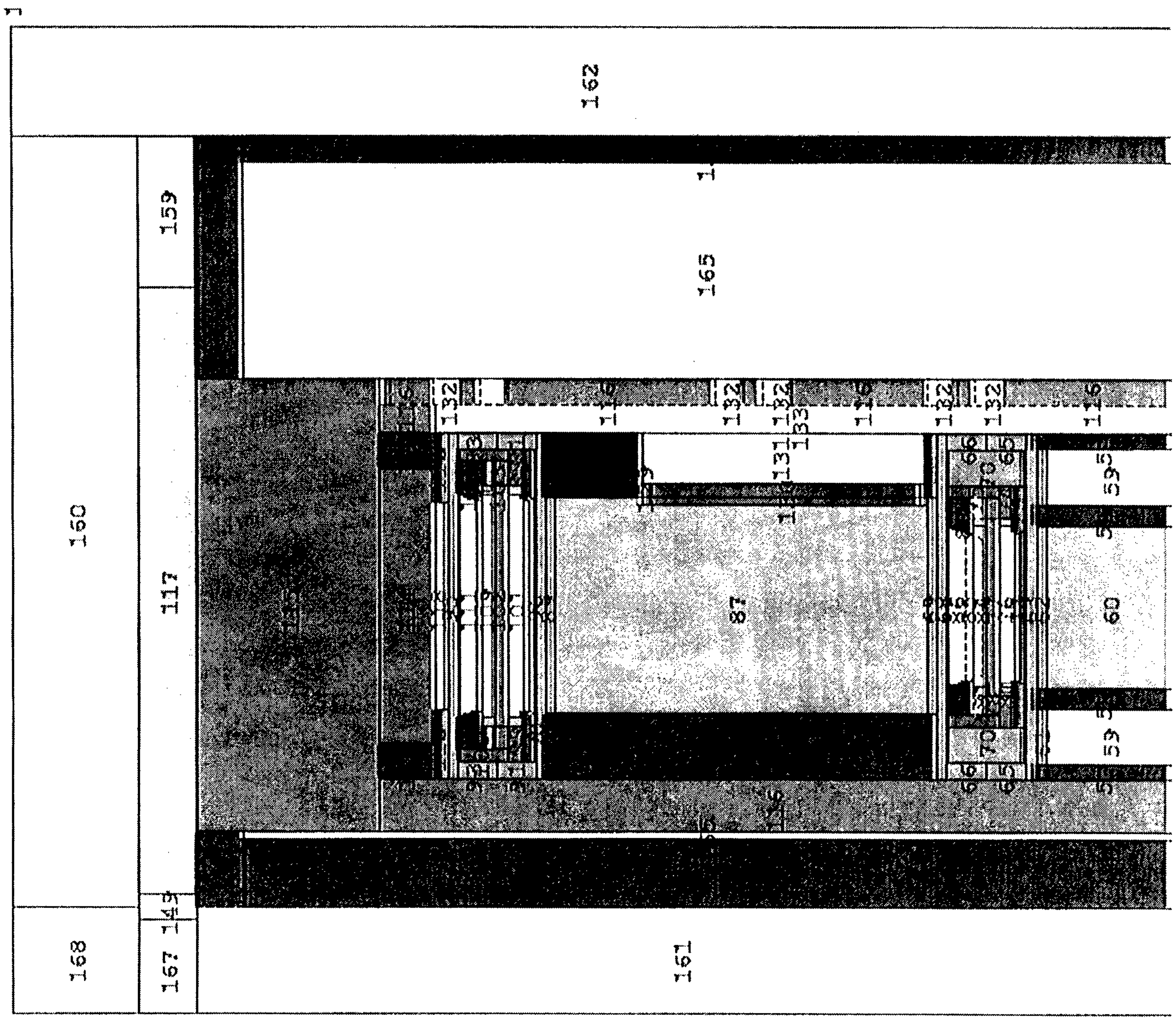

Figure 9(a). Partial (VISED) view of HEP (in-flight model) cell structure [6b].

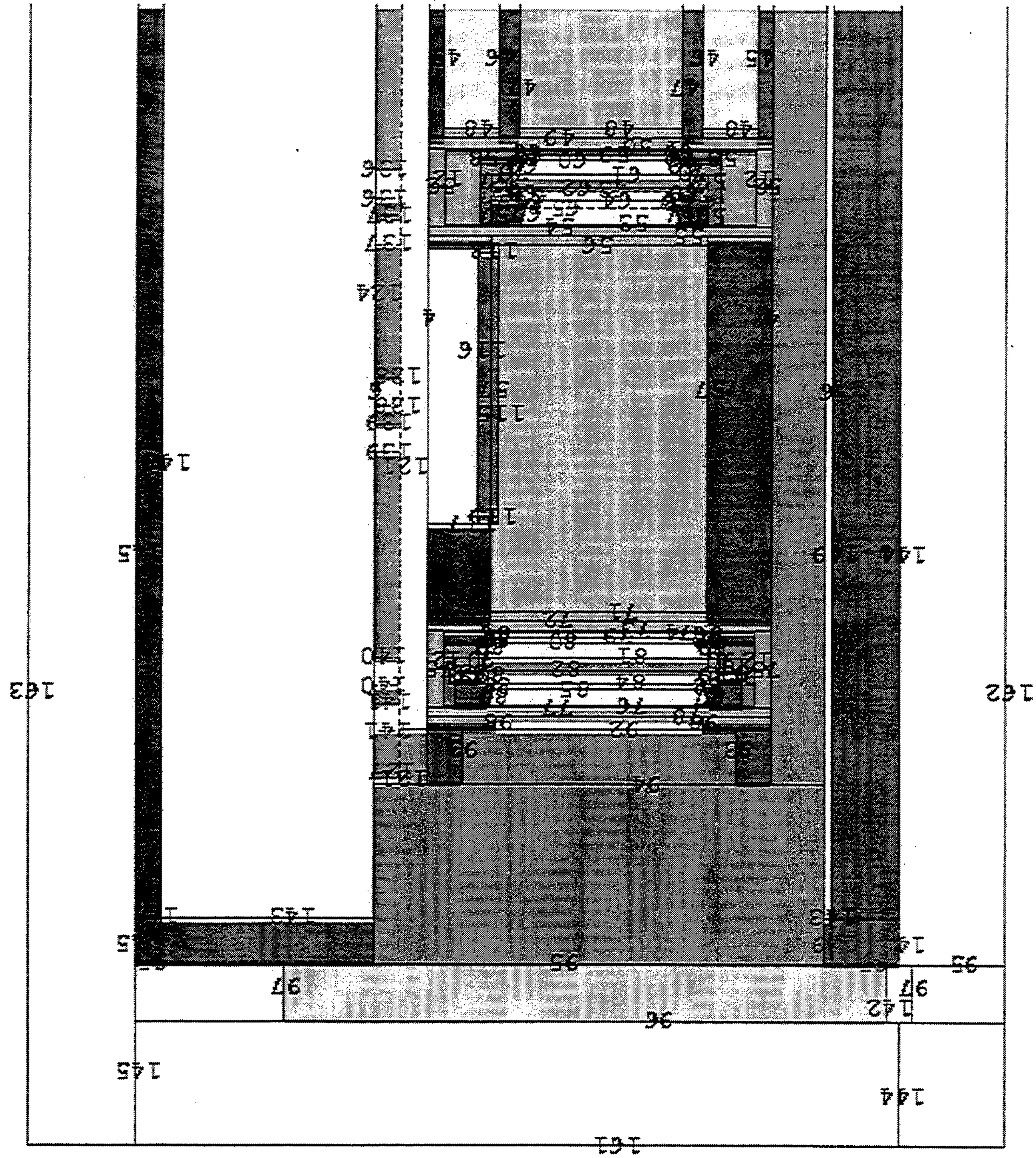

Figure 9(b). Partial (VISED) view of HEP (in-flight model) surface structure [6b].

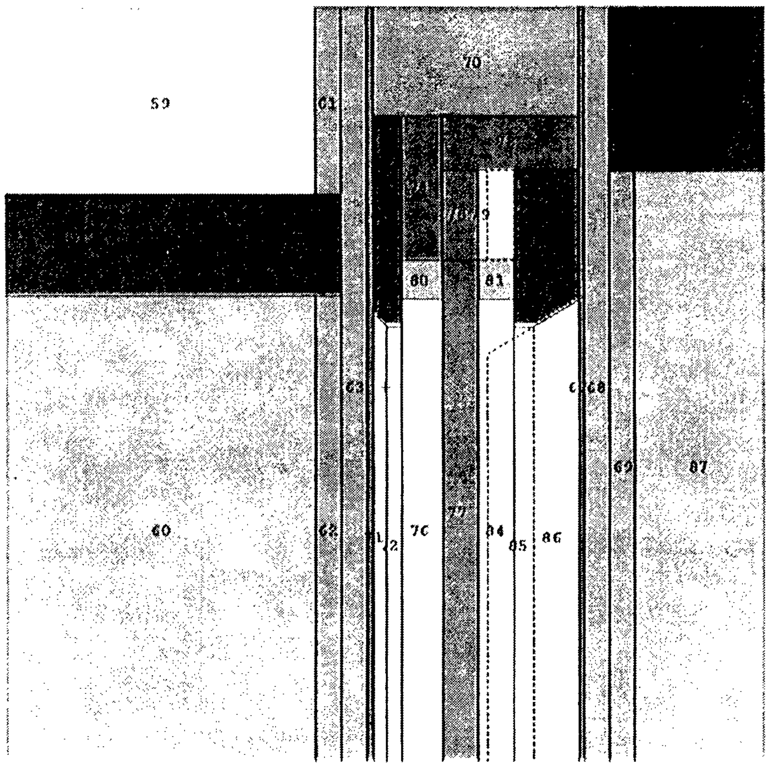

Figure. 10. Close-up (VISED) view of HEP silicon detector (D3) area (in-flight model) cell structure [6b].

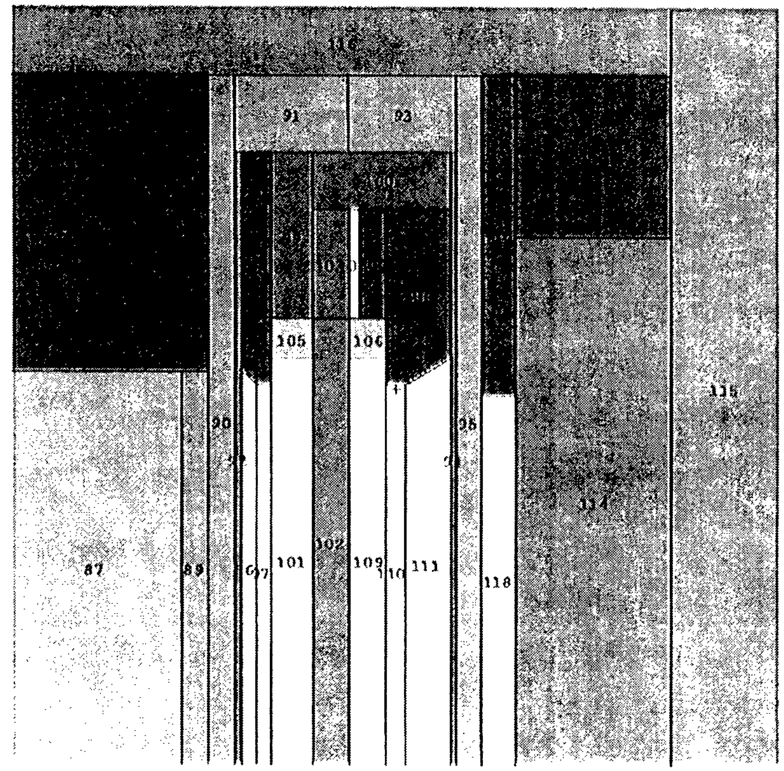

Figure 11. Close-up (VISED) view of HEP silicon detector (D4) area (in-flight model) cell structure [6b].

5. Electron Transport Modeling

5.1 ACCEPT[2c] Simulations for the CEASE Telescope

Electron transport calculations were made with the ITS-ACCEPT[2c] code for the Compact Environmental Anomaly Sensor (CEASE) Telescope (Figure 1). As was stated in earlier sections, while MCNPX and its MCNP predecessors provide the most complete and efficient method for modeling problem geometries for the largest variety of transported particles, the ITS codes, written specifically to handle problems in coupled electron/photon transport, is more efficient for this application. The amount of effort required on the part of the modeler is perhaps more than is needed for the MCNPX models, however, if interest is limited to electron/photon transport, the economy gained in computational effort provides more than sufficient reason for using ITS-ACCEPT.

The modeling techniques of ACCEPT and MCNPX differ fundamentally. In working with the MCNP codes, the user constructs the bodies making up the whole (*e.g.* CEASE telescope) by first defining the surfaces that enclose it, and then specifying whether a point inside the body lies within (negative in the mathematical sense) or without (positive in the mathematical sense) a surface. In most instances the mathematical sense of a body with respect to a surface is obvious, however when it is not, one need only substitute the point coordinates into the equation for the surface. The mathematical sense is provided by the sign of the number that results from this substitution.

ACCEPT code modeling accomplishes essentially the same thing using the combinatorial geometry method. ACCEPT allows the user to choose from a collection of body types: arbitrarily oriented box(BOX); rectangular parallelepiped(RPP); sphere(SPH); right circular(RCC) and elliptical cylinders(REC); ellipsoid(ELL); truncated cone(TRC); wedge(WED); arbitrary polyhedron(ARB). The user specifies the set of cells required to describe in the modeled structure by specifying appropriate combinations of bodies, such as intersections, unions and differences.

Figure 12 is a drawing of the labeled bodies for the CEASE telescope. Our choice of the arrangement and number of bodies used for this modeling task is not unique. However, we chose to define a large number of bodies which could then be logically combined in the simplest of ways to form the material cells rather than taking unnecessary error risks associated with using a smaller number of bodies combined in logically complicated ways. For the CEASE telescope without the frame and case, a total of 205 bodies and 205 cells were defined. Figure 13 is the corresponding drawing of the labeled cells.

An ACCEPT input file for the CEASE telescope with frame and case is given in Appendix 5. The addition of the frame and case to the telescope description increased the total numbers of bodies and cells to 259. The order of the geometry input data is bodies first (*i.e.* RCC, TRC, RPP), then cells, formed by the logical addition and subtraction of bodies. This is followed by a block of data containing the cell volumes (optional) listed in the order in which the cells are labeled (*i.e.* Z1, Z2, *etc.*) and a block of data containing the cell material numbers, ordered as listed in the XGEN input file (Appendix 6). The XGEN program is run before ACCEPT to produce the cross section tables for all the materials of the problem. The input file sets up a 25000 case history ACCEPT run for a 9.9 MeV electron beam normally incident on the top of the

the aluminum case. The beam cross sectional area is a disk of radius 1.4 cm with its center located on the CEASE axis of symmetry.

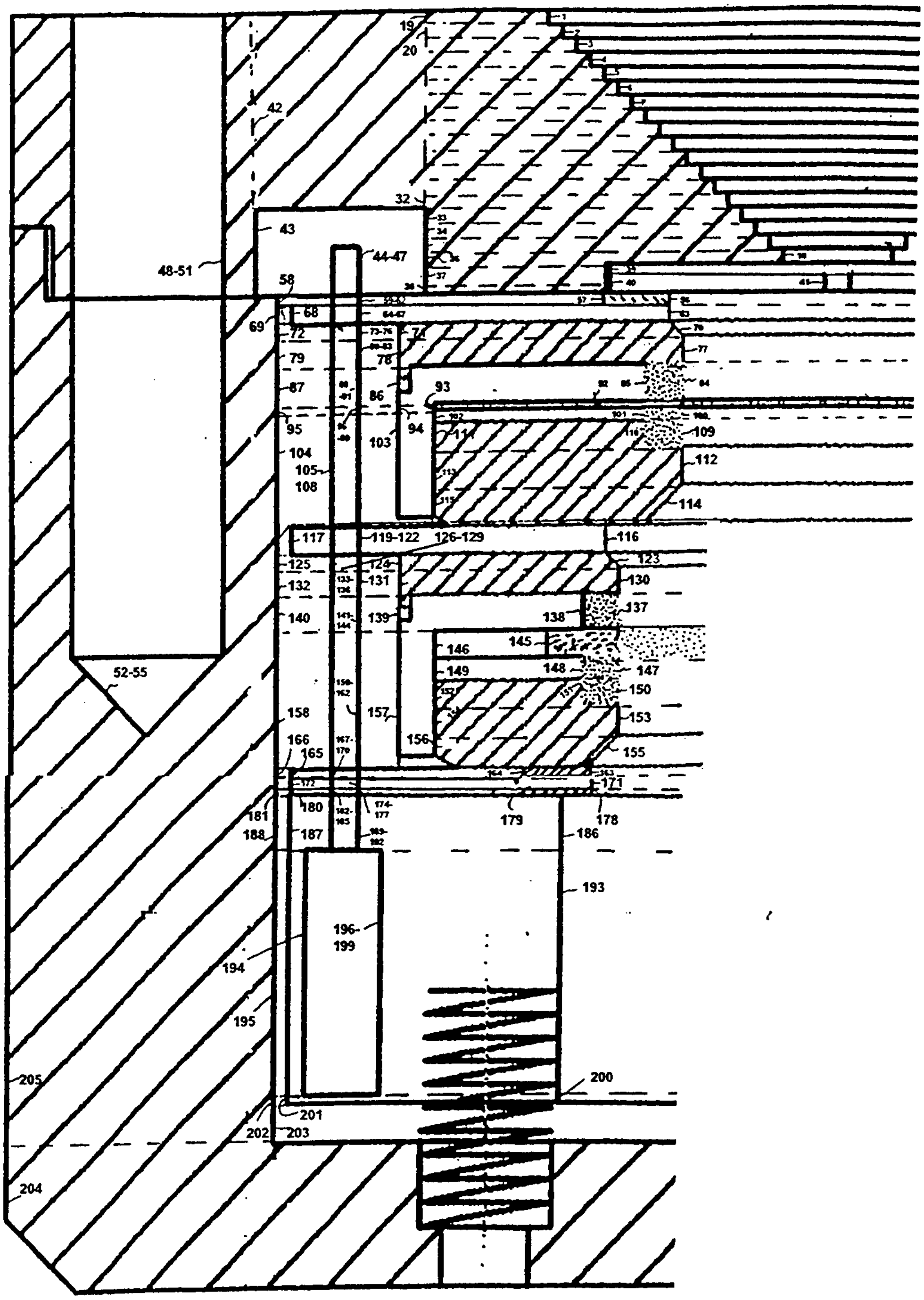

Figure 12. ACCEPT Body Definition Diagram for CEASE Telescope. The body labels correspond to those listed in the input file of Appendix 5.

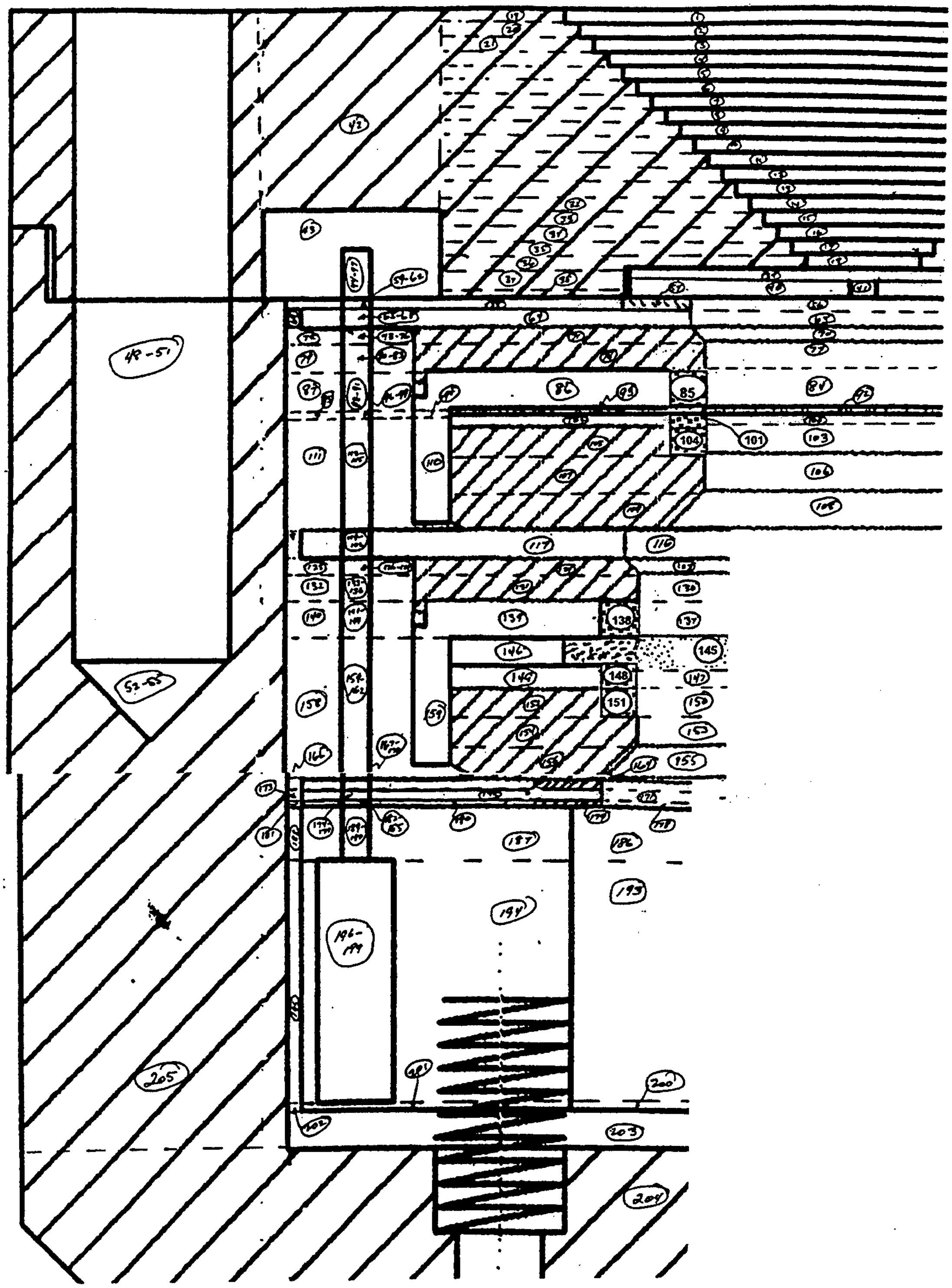

Figure 13. ACCEPT Cell Definition Diagram for CEASE Telescope. The cell labels correspond to those listed in the input file of Appendix 5 and the energy and charge deposition output listing of Appendix 7.

A partial listing of the ACCEPT output produced with the input file of Appendix 5, energy and charge deposition tables for the 259 cells, is given in Appendix 7.

Two sets of ACCEPT runs were made for the CEASE telescope: (1) telescope without frame and case; (2) telescope with frame and case. For each configuration, the runs were made for two beam energies, 9.9 and 6.0 MeV, with three incident obliquities, 0, 20, and 45° (w.r.t. telescope axis). The six disc sources for both configurations (1) and (2) were positioned above the telescope top (configuration 1) and above the case top (configuration 2) with the disc center located on the telescope axis. Additionally, one case was run for each configuration in which a disc source of 9.9 MeV electrons was assumed normally incident on the case bottom, again with the disc center located on the telescope axis of symmetry. The purpose of this investigation was to obtain a rough estimate of the extent to which the structure surrounding the telescope would affect the resulting energy and charge deposition within the telescope. The data shown in Table 1 provides some insight in this regard.

Table 1.

Total Energy and Charge Deposition in CEASE Telescope, Frame and Case from 9.9 and 6.0 MeV Electron Beams Incident at 0, 20, and 45° through Telescope Top and 0° through Case Bottom.

Electron beam Energy; Direction	instrument	case	total	inst.w/o case
	Energy deposition			
9.9 MeV normal	0.77382E+01	0.98642E+00	0.87247E+01	0.84380E+01
9.9 MeV 20 deg	0.75919E+01	0.10310E+01	0.86229E+01	0.82880E+01
9.9 MeV 45 deg	0.60965E+01	0.21474E+01	0.82439E+01	0.71770E+01
6.0 MeV normal	0.45763E+01	0.95720E+00	0.55335E+01	0.54070E+01
6.0 MeV 20 deg	0.46264E+01	0.86886E+00	0.54952E+01	0.53660E+01
6.0 Mev 45 deg	0.37229E+01	0.16593E+01	0.53822E+01	0.46580E+01
9.9 Mev rear norm	0.32799E+00	0.79876E+01	0.83156E+01	0.83330E+01
	Charge deposition			
	instrument	case	total	inst.w/o case
9.9 MeV normal	0.90898E+00	0.19200E-01	0.92818E+00	0.90220E+00
9.9 MeV 20 deg	0.85370E+00	0.53040E-01	0.90674E+00	0.87170E+00
9.9 MeV 45 deg	0.66500E+00	0.11592E+00	0.78092E+00	0.73680E+00
6.0 MeV normal	0.88382E+00	0.42400E-01	0.92622E+00	0.91440E+00
6.0 MeV 20 deg	0.84804E+00	0.70440E-01	0.91848E+00	0.90540E+00
6.0 Mev 45 deg	0.67350E+00	0.18088E+00	0.85438E+00	0.76990E+00
9.9 Mev rear norm	0.95680E-01	0.51846E+00	0.61414E+00	0.85820E+00

The effects on energy deposition of surrounding the telescope with the frame and case differ with electron beam energy. For the 9.9 MeV electron sources entering through the case top, the energy deposited in the telescope surrounded by the case varies from 92% to 85% of the amount of energy that would be deposited in the bare telescope, depending on incident angle. Because

the radius of the electron source "disk" is 1.4 cm, and the telescope aperture radius is ~0.5 cm, the area of the top plate directly exposed to the source is about 7 times larger than the aperture area. Therefore, depending on the direction of incidence, a significant fraction of the energy deposited in the case-frame structure is deposited in the top plate. This fraction varies from 85% (normal incidence) down to 38% (45° slant incidence) of the total energy deposited. For the 9.9 MeV electrons entering through the case bottom, the shielding effect of the case is dramatically increased. The energy deposited in the shielded telescope is approximately 4% of the energy that would be deposited by electrons entering the bare telescope through the bottom.

As might be expected, the shielding effect of the case is slightly greater for the 6.0 MeV electron sources, where energy deposited in the shielded telescope varies from 85% to 80% of the amount that would be deposited in the bare telescope. Of the total energy deposited in the case, 96% is deposited in the top plate (normal incidence) compared with 57% (45° slant incidence).

The results here indicate that realistic estimates of electron energy deposition in the CEASE telescope due to electron background in space can be made in a two-step process: (1) estimate the energy-angle distribution of electrons incident on the copper sheath encasing the CEASE telescope by running a set of simulations with electron beam sources with incident energies sampled from a "typical" space electron energy spectrum (the beam sources should be impingent on the case for a sufficient number of incident angles to permit simulation of arbitrary angular distributions by superposition); (2) utilize the energy-angle flux distributions of electrons obtained from step 1 to construct electron sources at the telescope exterior surface. Since the CEASE telescope assembly is mounted on the satellite exterior, only electrons incident on the side and top surfaces of the telescope need be considered.

5.2 CYLTRAN[2b] Simulation for the CEASE Telescope

Application of the CYLTRAN[2b] code is restricted to approximating problem geometries with total cylindrical symmetry. While this symmetry condition does not hold strictly for the CEASE telescope, if the stainless bolts and PMMA rods can be ignored, considerable economy of computational effort will result. CYLTRAN code runs generally require far less computer time than comparable ACCEPT runs, and the CYLTRAN geometry description file is usually about half as large as that required for ACCEPT and is easier to construct. These reasons justified our running the same source problem on the CEASE telescope with both programs. If equivalent, or near equivalent, results were to be obtained with both codes, then: (1) the likelihood is high that both codes are being used to properly simulate the electron/photon transport in the CEASE telescope; and (2) in situations where the effects of the case and frame can be ignored, CYLTRAN might be the preferable choice.

CYLTRAN was run for the 6.0 MeV normally incident electron source (1.4 cm radius disk source). The CYLTRAN energy and charge deposition results were compared with their ACCEPT counterparts. The direct comparison was made by dividing the CEASE geometry into 24 sections, *i.e.* clusters of ACCEPT and CYLTRAN cells describing the same geometry segments. These 24 sections, outlined with the colored lines, are labeled in Figure 14. Table 2 lists the energy deposition results from ACCEPT alongside the CYLTRAN data for the 24 sections. The CYLTRAN results closely track those obtained with ACCEPT. This was achieved with a CYLTRAN run time of 105 sec compared with 5900 sec for ACCEPT.

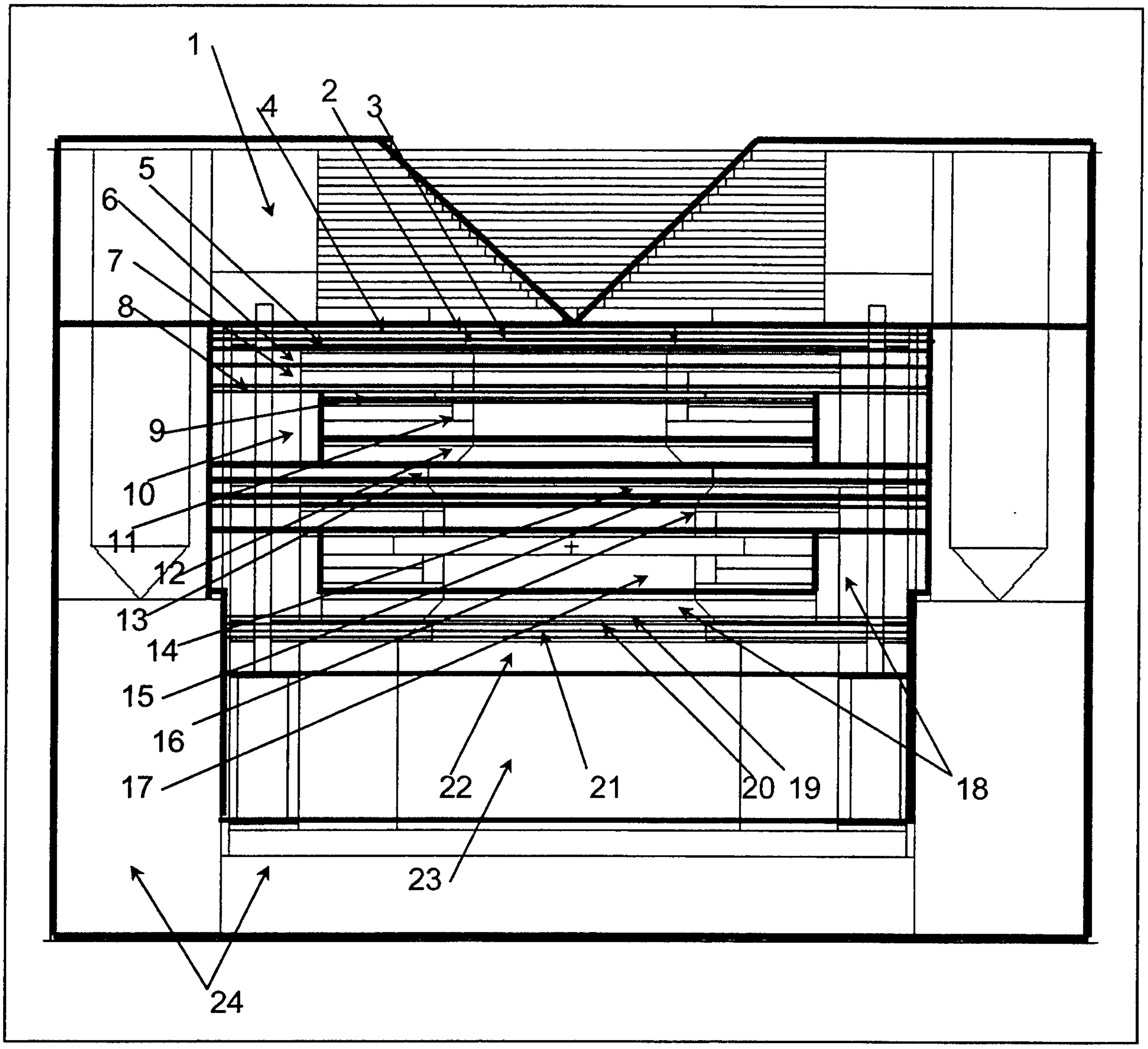

Figure 14. Cell clusters (24) comprising common definition of CEASE telescope geometry sections, regions outlined with (▬▬) for both ACCEPT and CYLTRAN. ACCEPT and CYLTRAN energy deposition results for 6 MeV electron source, normally incident on top, are compared in Table 2.

Table 2. Comparison of ACCEPT and CYLTRAN Energy Deposition Calculations for CEASE Telescope
(6 MeV electron source normally incident on top surface)

CELL	ENERGY DEPOSITION (MeV)	
(see Fig. 14)	ACCEPT	CYLTRAN
1	0.30264E+01	0.30172E+01
2	0.74210E-03	0.59331E-03
3	0.00000E+00	0.00000E+00
4	0.59560E-02	0.53913E-02
5	0.37657E-02	0.38671E-02
6	0.62859E-02	0.62188E-02
7	0.34803E-02	0.33354E-02
8	0.13232E-02	0.11061E-02
9	0.80120E-03	0.99519E-03
10	0.43820E-03	0.50560E-03
11	0.11522E-01	0.93524E-02
12	0.32310E-02	0.25409E-02
13	0.16880E-02	0.16472E-02
14	0.26630E-02	0.23131E-02
15	0.12930E-02	0.10255E-02
16	0.17821E-02	0.14628E-02
17	0.71571E-02	0.62222E-02
18	0.14257E-02	0.16183E-02
19	0.52870E-03	0.49061E-03
20	0.93790E-03	0.96860E-03
21	0.30940E-03	0.39563E-03
22	0.45900E-03	0.50587E-03
23	0.00000E+00	0.27694E-02
24	0.21214E+01	0.23492E+01
Total	0.54070E+01	0.54200E+01

6. Summary

During the period covered by this report, the technical progress achieved consisted of: (1) research, evaluation and selection of the available particle transport simulation programs for modeling the detection and measurement of space radiation by space-borne sensors; (2) construction of realistic (CEASE, HEP) sensor computer models and the performance of particle transport calculations; (3) analysis of transport simulation results, including single particle tracking; (4) transfer, including assistance and advice for implementation by the AFRL research personnel, of particle transport simulation technology to AFRL.

As indicated by the examples given in this report, several computer programs for particle transport simulation were applied to the modeling of the CEASE and HEP sensors. These programs are LAHET (proton source; proton, neutron, gamma, meson transport), ITS-ACCEPT and CYLTRAN (electron or gamma-photon sources; coupled electron/photon transport) and MCNPX (proton, electron, gamma-photon, neutron,....,alpha sources; 34 transportable particles/antiparticles). In addition, a preliminary version of a post-processor program for analysis of single particle histories from MCNPX was written. Shown in this report are several listings of input files, with geometry/materials drawings, for the various simulation programs, an example of (excerpt from) a track file analysis, and partial listings of code outputs.

We have also provided some explanation of the input parameter options available to the code user, with particular emphasis on the MCNPX code which, among all of the programs discussed, affords the highest degree of sensor geometry realism and the most flexible set of options to the researcher.

Based on our recommendations, the ITS codes, MCNP-Ver.4C, MCNPX-Ver.2.1.5, and MCNP-VISED have been acquired by AFRL. We have made available to the sponsor copies of the geometry/materials input files for the CEASE and HEP for use with these codes. We look forward to continuing this research effort by providing simulation calculations and results to the sponsor, making code modifications where needed, and performing in an advisory capacity on the use of the codes. We will, as we already have, continually update our research on the latest in particle transport simulation program development by maintaining contact with the codes' authors.

7. References

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   (a) J. A. Halbleib and W. H. Vandevender, TIGER – A one-dimensional, multilayer electron/photon Monte Carlo transport code, *Nucl. Sci. Eng.*,**57**, 94 (1975)

   (b) J. A. Halbleib and W. H. Vandevender, CYLTRAN – A cylindrical geometry, multimaterial electron/photon Monte Carlo transport code, *Nucl. Sci. Eng.*,**61**, 288 (1976)

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10. ARCON Corp. Contract No. 373, 1 Nov. 1995 – 31 March 1997.

APPENDIX 1

Annotated LAHET Input Data File for the CEASE Telescope, Frame and Case (surface, cell numbers refer to those shown in Figures 2 and 3, excepting frame and case)

```
lahet - CEASE Flight Sensor with Case geometry 300 MeV
In aperture normal incidence source - 200 protons

200,1,10,0,7*,1/
-1,-1/
1,0,0,7*/
300.,1.,1./
0,2,0/                          $ Brass mat. 1
29.0,63.546,0.056594,0/
28.0,58.71,0.026252,0/
0,1,0/                          $ Aluminum mat. 2
13.0,26.98,0.060275,0/
0,3,0/                          $ Tungsten mat. 3
74.0,183.855,0.05602028,0/
28.0,58.71,0.006463106,0/
29.0,63.546,0.002559106,0/
0,1,0/                          $ Gold mat. 4
79.0,196,9665,0.0577328,0/
0,9,0/                          $ Micarta FR-4 mat. 5
8.0,15.9994,0.04438845,0/
14.0,28.0855,0.01374926,0/
20.0,40.08,0.005455978,0/
13.0,26.98,0.0036012,0/
5.0,10.81,0.002197474,0/
12.0,24.305,0.001897872,0/
11.0,22.9898,0.000987328,0/
26.0,55.847,0.000350574,0/
22.0,47.90,0.0001148818,0/
0,5,0/                               $ Stainless mat. 6
25.0,54.9380,0.0057,0/
14.0,28.0855,0.00172,0/
24.0,51.996,0.01575,0/
28.0,58.71,0.00369,0/
26.0,55.847,0.06126,0/
0,6,0/          $ Conductive silicone elastomer mat. 7
14.0,28.0855,0.015175,0/
8.0,15.9994,0.0151619,0/
6.0,12.001,0.0303763,0/
1.0,1.0079,0.091092,0/
28.0,58.71,0.0288999,0/
47.0,107.868,0.0155626,0/
0.057272,2,0/                    $ PMMA mat. 8
6.0,12.011,0.035795,0/
8.0,15.9994,0.014318,0/
0,1,0/                           $ Silicon mat. 9
14.0,28.0855,0.04967,0/
0,2,0/                          $ Copper alloy  mat. 10
29.0,63.546,0.08412257,0/
52.0,127.6,0.0002105217,0/
C
C    CELLS
C
    1    0                 -1  29  -30  $  begin collimator aperture
    2    0                 -2  30  -31
    3    0                 -3  31  -32
    4    0                 -4  32  -33
    5    0                 -5  33  -34
    6    0                 -6  34  -35
    7    0                 -7  35  -36
    8    0                 -8  36  -37
    9    0                 -9  37  -38
   10    0                -10  38  -39
   11    0                -11  39  -40
   12    0                -12  40  -41
   13    0                -13  41  -42
   14    0                -14  42  -43
```

```
15    0              -15 43   -44
16    0              -16 44   -45
17    0              -17 45   -46
18    0              -18 46   -47  $  end collimator aperture
19    10  -8.92      -21  1    29  -30  $ copper collimator
20    10  -8.92      -21  2    30  -31
21    10  -8.92      -21  3    31  -32
22    10  -8.92      -21  4    32  -33
23    10  -8.92      -21  5    33  -34
24    10  -8.92      -21  6    34  -35
25    10  -8.92      -21  7    35  -36
26    10  -8.92      -21  8    36  -37
27    10  -8.92      -21  9    37  -38
28    10  -8.92      -21  10   38  -39
29    10  -8.92      -21  11   39  -40
30    10  -8.92      -21  12   40  -41
31    10  -8.92      -21  13   41  -42
32    10  -8.92      -21  14   42  -43
33    10  -8.92      -21  15   43  -44
34    10  -8.92      -21  16   44  -45
35    10  -8.92      -21  17   45  -46
36    10  -8.92      -21  18   46  -47
37    10  -8.92      -21  19   47  -48
38    10  -8.92      -21  19   48  -49
39    2   -2.7       -19  47  -48       $ aluminum foil light shield
40    3   -18.0      -19  20   48  -49   $ tungsten collimator disk
41    0              -104  49   19  -51 #111 #112 #113 #114  $ void annulus
42    0              -20  48  -49       $ void
43    4   -18.88     -19  53   49  -51  $ gold annulus between tungsten and PCB
44    0              -53  49  -51       $ void interior to gold annulus
45    0              -104  89  -95   51     $ void annulus space next to copper case
46    5   -2.54      -89  53   51  -52 #111 #112 #113 #114  $ PCB annulus
47    0              -53  51  -52   $ void space at center of PCB annulus
48    10  -8.92       21 -22   29  -43  $ copper collimator section
49    0               21 -22   43  -49 #111 #112 #113 #114  $ void annulus in collimator
50    10  -8.92       22 -24   29 -106   #52 #53  #54  #55
                                         #56 #57  #58  #59  $copper case section
51    10  -8.92       49 -106  104 -22 $ copper case section
52    6   -8.0        29 -105  -25  $ stainless bolt
53    6   -8.0        29 -105  -26  $ stainless bolt
54    6   -8.0        29 -105  -27  $ stainless bolt
55    6   -8.0        29 -105  -28  $ stainless bolt
56    6   -8.0       105 -109      $ stainless bolt tip
57    6   -8.0       105 -110      $ stainless bolt tip
58    6   -8.0       105 -111      $ stainless bolt tip
59    6   -8.0       105 -112      $ stainless bolt tip
60    0              -55    52  -56   $ void center of brass mounting for DFT
61    1   -8.53       55    52  -59  -56 $ brass annulus mounting for DFT
62    1   -8.53       56    58  -59  -57 $ brass annulus mounting for DFT
63    0               56   -58  -57   $ void center of brass mounting for DFT
64    0               57   -58  -68   $ void center of brass mounting for DFT
65    7   -7.4723     57    58  -61  -68 $ rubber mounting spacer for DFT
66    8   -1.19       57   -59   61  -68 $ PMMA spacer for DFT
67    3   -2.33      -67    68  -69   $ DFT, electrically active part
68    0               59   -89   52 -72 #111 #112 #113 #114 $ void
69    3   -2.33       67   -62  68   -69 $ DFT, electrically inactive part
70    8   -1.19      -59    68  62  -72  $ PMMA spacer for DFT
71    0               69   -70  61  -62 $ void space between DFT and brass mounting
72    7   -7.4723     69  -107  58  -61 $ rubber mounting spacer for DFT
73    0               69    -71 -58 $ void center below DFT
74    1  -8.53             -107   70  -62   61 $ brass annulus mounting for DFT
75    1  -8.53              107  -71   58  -62  $ brass annulus mounting for DFT
76    1  -8.53               71   73  -72  -62   $ brass annulus mounting for DFT
77    0                     -73   71  -72  $ void center below DFT
78    5  -2.54               75   72  -74  -89 #111 #112 #113 #114 $ PCB annulus
79    0                      59  -89   74  -91 #111 #112 #113 #114  $ void
80    0                     -75   72  -74   $ void at center of PCB annulus
81    0                      74  -77  -113   $ void at center of brass mounting for DBT
82    1  -8.53              113   74  -77  -59 $ brass annulus mounting for DBT
83    1  -8.53               77  -78   76  -59  $ brass annulus mounting for DBT
84    0                      77  -79  -76     $ void at center of brass mounting for DBT
85    7  -7.4723             78  -79   76 -108  $ rubber spacer for DBT
86    8  -1.19               78  -79  108  -59  $ PMMA spacer for DBT
87    8  -1.19               79  -85   62  -59  $ PMMA spacer for DBT
88    3  -2.33               79  -81  -80     $ DBT, electrically active part
89    3  -2.33               79  -81   80  -62  $ DBT, electrically inactive part
```

```
   90    0                        -62   81  -82  108 $ void space between DBT and brass mounting
   91    7  -7.4723                81  -83   76 -108 $ rubber spacer for DBT
   92    0                         81  -84  -76  $ void at center of brass mounting for DBT
   93    1  -8.53                  82  -83  108  -62 $ brass annulus mounting for DBT
   94    1  -8.53                  83  -84  -62   76 $ brass annulus mounting for DBT
   95    1  -8.53                  84  -85  -62   86 $ brass annulus mounting for DBT
   96    0                         84  -85  -86    $ void at center of brass mounting for DBT
   97    0                         85  -87  -93      $ void at center of PCB annulus
   98    0                         88   85  -91  -89 #111 #112 #113 #114 $ void annulus above PCB
   99    4  -18.88                 85  -91  -88   87 $ gold spacer annulus on PCB
  100    5  -2.54                 -89   87   91  -92 #111 #112 #113 #114 $ PCB annulus
  101    0                         92  -93  -89   88 #111 #112 #113 #114  $ void annulus below PCB
  102    4  -18.88                 92  -93  -88   87 $ gold spacer annulus below PCB
  103    8  -1.19                  59  -89   93 -101 #111 #112 #113 #114 $PMMA base annulus section
  104    8  -1.19                 101   59  -89 -102 #115 #116 #117 #118 $PMMA base annulus section
  105    8  -1.19                  59  -89  102  -94  $ PMMA base annulus section
  106    8  -1.19                 -59   93   90  -94  $ PMMA base annulus section
  107    0                        -90   93  -94  $  void at center of base PMMA annulus
  108    0                         94  -95  -89  $ void below base PMMA annulus
  109    10  -8.92                 95  -96 -104  $ copper case bottom
  110    10  -8.92                106  -96  104 -24  $ copper case side/bottom
  111    8  -1.19                 103 -101  -63  $ PMMA rod
  112    8  -1.19                 103  101  -64  $ PMMA rod
  113    8  -1.19                 103  101  -65  $ PMMA rod
  114    8  -1.19                 103 -101  -66  $ PMMA rod
  115    8  -1.19                 101  102  -97  $ PMMA rod
  116    8  -1.19                 101  102  -98  $ PMMA rod
  117    8  -1.19                 101  102  -99  $ PMMA rod
  118    8  -1.19                 101  102  -100 $ PMMA rod
C
C  outside case
C

  119    2  -2.7                  114 -29 117 -120 121 -124 #125 #139
                                  #140 #141 #142 $ Al top plate
  120    2  -2.7                  115 -116 117  -120 121 -124  #139
                                  #140 #141 #142 $Al bot plate
  121    2  -2.7                  117 -118 29  -115 121 -124 $ low x-side plate
  122    2  -2.7                  119 -120 29  -115 121 -124 $ high x-side plate
  123    2  -2.7                  121 -122 29  -115 118 -119 $ low y-side plate
  124    2  -2.7                  123 -124 29  -115 118 -119 $ high y-side plate
  125    0                         114  -29  -1  $ hole in case top for aperture
  126    5  -2.54   96 -125 118 -119 122 -123 #142 #139 #140 #141 $ micarta board
  127    5  -2.54   126 -127 118 -119 122 -123 #142 #139 #140 #141 $ micarta board
  128    5  -2.54   128 -129 118 -119 122 -123 #142 #139 #140 #141 $ micarta board
  129    5  -2.54   130 -131 118 -119 122 -123 #142 #139 #140 #141 $ micarta board
  130    5  -2.54   132 -133 118 -119 122 -123 #142 #139 #140 #141 $ micarta board
  131    5  -2.54   134 -135 118 -119 122 -123 #142 #139 #140 #141 $ micarta board
132 0   29 -96 118 -119 122 -123  24 #139 #140 #141 #142
        $ Void between top Al plate and top micarta board; excludes corner bolts and telescope
  133     0 #139 #140 #141 #142 #143 #149 #155 #161
         125 -126 118 -119 122 -123 $ void between boards
  134     0 #139 #140 #141 #142 #144 #150 #156 #162
         127 -128 118 -119 122 -123 $ void between boards
  135     0 #139 #140 #141 #142 #145 #151 #157 #163
         129 -130 118 -119 122 -123 $ void between boards
  136     0 #139 #140 #141 #142 #146 #152 #158 #164
         131 -132 118 -119 122 -123 $ void between boards
  137     0  #139 #140 #141 #142 #147 #153 #159 #165
         133 -134 118 -119 122 -123 $ void between boards
  138     0 #139 #140 #141 #142 #148 #154 #160 #166
         135 -115 118 -119 122 -123 $ void between boards
  139    6 -8.0  -136 -116 114 $ Stainless corner bolt (case)
  140    6 -8.0  -137 -116 114 $ Stainless corner bolt (case)
  141    6 -8.0  -138 -116 114 $ Stainless corner bolt (case)
  142    6 -8.0  -139 -116 114 $ Stainless corner bolt (case)
  143    8 -1.19 136 -140 #139 125 -126  $ PMMA spacer wrapped around stainless corner bolt
  144    8 -1.19 136 -140 #139 127 -128  $ PMMA spacer wrapped around stainless corner bolt
  145    8 -1.19 136 -140 #139 129 -130  $ PMMA spacer wrapped around stainless corner bolt
  146    8 -1.19 136 -140 #139 131 -132  $ PMMA spacer wrapped around stainless corner bolt
  147    8 -1.19 136 -140 #139 133 -134  $ PMMA spacer wrapped around stainless corner bolt
  148    8 -1.19 136 -140 #139 135 -115  $ PMMA spacer wrapped around stainless corner bolt
  149    8 -1.19 137 -141 #140 125 -126  $ PMMA spacer wrapped around stainless corner bolt
  150    8 -1.19 137 -141 #140 127 -128  $ PMMA spacer wrapped around stainless corner bolt
  151    8 -1.19 137 -141 #140 129 -130  $ PMMA spacer wrapped around stainless corner bolt
  152    8 -1.19 137 -141 #140 131 -132  $ PMMA spacer wrapped around stainless corner bolt
```

```
153    8 -1.19 137 -141 #140 133 -134   $ PMMA spacer wrapped around stainless corner bolt
154    8 -1.19 137 -141 #140 135 -115   $ PMMA spacer wrapped around stainless corner bolt
155    8 -1.19 138 -142 #141 125 -126   $ PMMA spacer wrapped around stainless corner bolt
156    8 -1.19 138 -142 #141 127 -128   $ PMMA spacer wrapped around stainless corner bolt
157    8 -1.19 138 -142 #141 129 -130   $ PMMA spacer wrapped around stainless corner bolt
158    8 -1.19 138 -142 #141 131 -132   $ PMMA spacer wrapped around stainless corner bolt
159    8 -1.19 138 -142 #141 133 -134   $ PMMA spacer wrapped around stainless corner bolt
160    8 -1.19 138 -142 #141 135 -115   $ PMMA spacer wrapped around stainless corner bolt
161    8 -1.19 139 -143 #142 125 -126   $ PMMA spacer wrapped around stainless corner bolt
162    8 -1.19 139 -143 #142 127 -128   $ PMMA spacer wrapped around stainless corner bolt
163    8 -1.19 139 -143 #142 129 -130   $ PMMA spacer wrapped around stainless corner bolt
164    8 -1.19 139 -143 #142 131 -132   $ PMMA spacer wrapped around stainless corner bolt
165    8 -1.19 139 -143 #142 133 -134   $ PMMA spacer wrapped around stainless corner bolt
166    8 -1.19 139 -143 #142 135 -115   $ PMMA spacer wrapped around stainless corner bolt
167    0  144 -114  146 -147 148 -149   $ exterior void region (1 cm thick)  above top z plate
168    0  116 -145  146 -147 148 -149   $ exterior void region(1 cm thick) below bottom z plate
169    0  146 -117  148 -149 114 -145   $ exterior void region (1 cm thick)outside lower x plate
170    0  120 -147  148 -149 114 -145   $ exterior void region(1 cm thick) outside upper x plate
171    0  117 -120  148 -121 114 -145   $ exterior void region(1 cm thick)outside lower y plate
172    0  117 -120  124 -149 114 -145   $ exterior void region(1 cm thick)outside upper y plate
173    0 -144:-148: 145:149:-146:147    $ escape region

  1  cz  0.5334
  2  cz  0.5080
  3  cz  0.4826
  4  cz  0.4572
  5  cz  0.4318
  6  cz  0.4064
  7  cz  0.3810
  8  cz  0.3556
  9  cz  0.3302
 10  cz  0.3048
 11  cz  0.2794
 12  cz  0.2540
 13  cz  0.2286
 14  cz  0.2032
 15  cz  0.1778
 16  cz  0.1524
 17  cz  0.1270
 18  cz  0.1016
 19  cz  0.4191
 20  cz  0.02286
 21  cz  0.750711
 22  cz  1.06680
 24  cz  1.5240
 25  c/z  1.27 0.00 0.143111
 26  c/z  0.00 1.27 0.143111
 27  c/z -1.27 0.00 0.143111
 28  c/z 0.00 -1.27 0.143111
 29  pz  0.00000
 30  pz  0.02540
 31  pz  0.05080
 32  pz  0.07620
 33  pz  0.1016
 34  pz  0.1270
 35  pz  0.1524
 36  pz  0.1778
 37  pz  0.2032
 38  pz  0.2286
 39  pz  0.2540
 40  pz  0.2794
 41  pz  0.3048
 42  pz  0.3302
 43  pz  0.3556
 44  pz  0.3810
 45  pz  0.4064
 46  pz  0.4318
 47  pz  0.4572
 48  pz  0.4581
 49  pz  0.5080
 51  pz  0.51652
 52  pz  0.56732
 53  cz  0.3111
 55  kz  0.87842 1.0  -1
 56  pz  0.592208
 57  pz  0.64199
```

```
 58  cz   0.28622
 59  cz   0.8000
 61  cz   0.34844
 62  cz   0.73422
 63  c/z 0.9087555  0.00 0.0248889
 64  c/z 0.00  0.9087555 0.0248889
 65  c/z -0.9087555 0.00 0.0248889
 66  c/z 0.00 -0.9087555 0.0248889
 67  cz   0.4021
 68  pz   0.704212
 69  pz   0.719212
 70  pz   0.744212
 71  pz   0.856101
 72  pz   0.918323
 73  kz   0.569883 1.0  +1
 74  pz   0.969123
 75  cz   0.423111
 76  cz   0.373111
 77  pz   1.019123
 78  pz   1.043789
 79  pz   1.113477
 80  cz   0.518942
 81  pz   1.163477
 82  pz   1.203477
 83  pz   1.243477
 84  pz   1.293477
 85  pz   1.352774
 86  kz   0.920366 1.0 +1
 87  cz   0.4064
 88  cz   0.6096
 89  cz   1.001777
 90  cz   0.5080
 91  pz   1.360394
 92  pz   1.41119
 93  pz   1.41881
 94  pz   1.971965
 95  pz   2.046631
 96  pz   2.29552
 97  c/z 0.9087555  0.00 0.0734222
 98  c/z 0.00  0.9087555 0.0734222
 99  c/z -0.9087555 0.00 0.0734222
100  c/z 0.00 -0.9087555 0.0734222
101  pz   1.518365
102  pz   1.953921
103  pz   0.448143
104  cz   1.027288
105  pz   1.142666
106  pz   1.29200
107  pz   0.787657
108  cz   0.43533
109  k/z 1.27  0.00  1.292  0.8575536  -1
110  k/z 0.00  1.27  1.292  0.8575536  -1
111  k/z -1.27 0.00  1.292  0.8575536  -1
112  k/z 0.00 -1.27  1.292  0.8575536  -1
113  kz   1.392234 1.0  -1
114  pz   -.2032
115  pz   7.5565
116  pz   8.1661
117  px   -2.54
118  px   -2.3368
119  px   7.4168
120  px   7.62
121  py   -2.54
122  py   -2.3368
123  py   7.4168
124  py   7.62
125  pz   2.454275
126  pz   3.137535
127  pz   3.296285
128  pz   3.979545
129  pz   4.138295
130  pz   4.821555
131  pz   4.980305
132  pz   5.663565
133  pz   5.822315
134  pz   6.505575
```

```
    99  c/z -0.9087555 0.00 0.0734222
   100  c/z 0.00 -0.9087555 0.0734222
   101  pz  1.518365
   102  pz  1.953921
   103  pz  0.448143
   104  cz  1.027288
   105  pz  1.142666
   106  pz  1.29200
   107  pz  0.787657
   108  cz  0.43533
   109  k/z 1.27  0.00  1.292  0.8575536  -1
   110  k/z 0.00  1.27  1.292  0.8575536  -1
   111  k/z -1.27 0.00  1.292  0.8575536  -1
   112  k/z 0.00 -1.27  1.292  0.8575536  -1
   113  kz  1.392234 1.0  -1
   114  pz  -.2032
   115  pz  7.5565
   116  pz  8.1661
   117  px  -2.54
   118  px  -2.3368
   119  px  7.4168
   120  px  7.62
   121  py  -2.54
   122  py  -2.3368
   123  py  7.4168
   124  py  7.62
   125  pz  2.454275
   126  pz  3.137535
   127  pz  3.296285
   128  pz  3.979545
   129  pz  4.138295
   130  pz  4.821555
   131  pz  4.980305
   132  pz  5.663565
   133  pz  5.822315
   134  pz  6.505575
   135  pz  6.664325
   136  c/z  -1.79605  -1.79605  0.1058333
   137  c/z   5.82395  -1.79605  0.1058333
   138  c/z   5.82395   5.82395  0.1058333
   139  c/z  -1.79605   5.82395  0.1058333
   140  c/z  -1.79605  -1.79605  0.21167
   141  c/z   5.82395  -1.79605  0.21167
   142  c/z   5.82395   5.82395  0.21167
   143  c/z  -1.79605   5.82395  0.21167
   144  pz -1.2032
   145  pz 9.1661
   146  px -3.54
   147  px 8.62
   148  py -3.54
   149  py 8.62

in     1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
       1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
print

0,300,0.0,-1.0,0.25,0.25,,,0.0,0.0/
```

APPENDIX 2

Energy Deposition Audits (partial listing of HTAPE output)
For
300 MeV Proton Beam Source Entering CEASE through Telescope Aperture
(cell numbers refer to cells shown in Figure 3)

```
      listing of card input

      1      300 MeV Mass-Energy Deposition Audit 200 histories
      2      12/27/99  CEASE - normal beam on front face with case
      3      6,0,0,0,0,109/
      4      19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,
      5      35,36,37,38,39,40,43,46,48,50,
      6      51,52,53,54,55,56,57,58,59,61,62,65,66,
      7      67,69,70,72,74,75,76,78,82,
      8      83,85,86,87,88,89,91,93,94,95,
      9      99,103,105,106,109,110,
     10      111,112,113,114,115,116,117,118,
     11      119,120,121,122,123,124,126,127,128,129,
     12      130,131,139,140,141,142,143,144,145,146,
     13      147,148,149,150,151,152,153,154,155,156,
     14      160,161,162,163,164,165,166/
     15      /
1                     case  1

                     .
                     .
                     .
                     .
1                      case no.  1     option no.  6

          300 MeV Mass-Energy Deposition Audit 200 histories
          12/27/99  CEASE - normal beam on front face with case

                       energy deposition in cell  31

                          time total
 coulomb loss h-1        7.96533D-02 0.172
 coulomb loss pi+-       0.00000D+00 0.000
 coulomb loss mu+-       0.00000D+00 0.000
 coulomb loss K+-        0.00000D+00 0.000
 coulomb loss pbar       0.00000D+00 0.000
 coulomb loss h-2        0.00000D+00 0.000
 coulomb loss h-3        0.00000D+00 0.000
 coulomb loss he-3       0.00000D+00 0.000
 coulomb loss he-4       0.00000D+00 0.000
 nuclear recoil          0.00000D+00 0.000
 excitation              0.00000D+00 0.000
 pi0 decay gammas        0.00000D+00 0.000
 kin. eng. of e+,e-      0.00000D+00 0.000
 positron mass           0.00000D+00 0.000
 kin. eng. of muons      0.00000D+00 0.000
 mu+ mass                0.00000D+00 0.000
 mu- mass                0.00000D+00 0.000
 total deposition        7.96533D-02 0.172



1                      case no.  1     option no.  6

          300 MeV Mass-Energy Deposition Audit 200 histories
          12/27/99  CEASE - normal beam on front face with case

                       energy deposition in cell  32


                 time total
 coulomb loss h-1        1.61736D-01 0.110
 coulomb loss pi+-       0.00000D+00 0.000
```

```
 coulomb loss mu+-      0.00000D+00 0.000
 coulomb loss K+-       0.00000D+00 0.000
 coulomb loss pbar      0.00000D+00 0.000
 coulomb loss h-2       0.00000D+00 0.000
 coulomb loss h-3       0.00000D+00 0.000
 coulomb loss he-3      0.00000D+00 0.000
 coulomb loss he-4      0.00000D+00 0.000
 nuclear recoil         0.00000D+00 0.000
 excitation             0.00000D+00 0.000
 pi0 decay gammas       0.00000D+00 0.000
 kin. eng. of e+,e-     0.00000D+00 0.000
 positron mass          0.00000D+00 0.000
 kin. eng. of muons     0.00000D+00 0.000
 mu+ mass               0.00000D+00 0.000
 mu- mass               0.00000D+00 0.000
 total deposition       1.61736D-01 0.110
1                      case no.  1     option no.  6

          300 MeV Mass-Energy Deposition Audit 200 histories
          12/27/99  CEASE - normal beam on front face with case

                       energy deposition in cell  33

                          time total
 coulomb loss h-1       3.02573D-01 0.082
 coulomb loss pi+-      0.00000D+00 0.000
 coulomb loss mu+-      0.00000D+00 0.000
 coulomb loss K+-       0.00000D+00 0.000
 coulomb loss pbar      0.00000D+00 0.000
 coulomb loss h-2       0.00000D+00 0.000
 coulomb loss h-3       0.00000D+00 0.000
 coulomb loss he-3      0.00000D+00 0.000
 coulomb loss he-4      0.00000D+00 0.000
 nuclear recoil         0.00000D+00 0.000
 excitation             0.00000D+00 0.000
 pi0 decay gammas       0.00000D+00 0.000
 kin. eng. of e+,e-     0.00000D+00 0.000
 positron mass          0.00000D+00 0.000
 kin. eng. of muons     0.00000D+00 0.000
 mu+ mass               0.00000D+00 0.000
 mu- mass               0.00000D+00 0.000
 total deposition       3.02573D-01 0.082


                       case no.  1     option no.  6

          300 MeV Mass-Energy Deposition Audit 200 histories
          12/27/99  CEASE - normal beam on front face with case

                       energy deposition in cell  34

                          time total
 coulomb loss h-1       5.39551D-01 0.357
 coulomb loss pi+-      0.00000D+00 0.000
 coulomb loss mu+-      0.00000D+00 0.000
 coulomb loss K+-       0.00000D+00 0.000
 coulomb loss pbar      0.00000D+00 0.000
 coulomb loss h-2       0.00000D+00 0.000
 coulomb loss h-3       0.00000D+00 0.000
 coulomb loss he-3      0.00000D+00 0.000
 coulomb loss he-4      0.00000D+00 0.000
 nuclear recoil         9.41896D-03 1.000
 excitation             6.83015D-04 1.000
 pi0 decay gammas       0.00000D+00 0.000
 kin. eng. of e+,e-     0.00000D+00 0.000
 positron mass          0.00000D+00 0.000
 kin. eng. of muons     0.00000D+00 0.000
 mu+ mass               0.00000D+00 0.000
 mu- mass               0.00000D+00 0.000
 total deposition       5.49653D-01 0.368

1                      case no.  1     option no.  6

          300 MeV Mass-Energy Deposition Audit 200 histories
          12/27/99  CEASE - normal beam on front face with case
```

	time total	
coulomb loss h-1	4.29619D-01	0.039
coulomb loss pi+-	0.00000D+00	0.000
coulomb loss mu+-	0.00000D+00	0.000
coulomb loss K+-	0.00000D+00	0.000
coulomb loss pbar	0.00000D+00	0.000
coulomb loss h-2	0.00000D+00	0.000
coulomb loss h-3	0.00000D+00	0.000
coulomb loss he-3	0.00000D+00	0.000
coulomb loss he-4	0.00000D+00	0.000
nuclear recoil	0.00000D+00	0.000
excitation	0.00000D+00	0.000
pi0 decay gammas	0.00000D+00	0.000
kin. eng. of e+,e-	0.00000D+00	0.000
positron mass	0.00000D+00	0.000
kin. eng. of muons	0.00000D+00	0.000
mu+ mass	0.00000D+00	0.000
mu- mass	0.00000D+00	0.000
total deposition	4.29619D-01	0.039

1 case no. 1 option no. 6

300 MeV Mass-Energy Deposition Audit 200 histories
12/27/99 CEASE - normal beam on front face with case

energy deposition in cell 36

	time total	
coulomb loss h-1	5.21322D-01	0.101
coulomb loss pi+-	0.00000D+00	0.000
coulomb loss mu+-	0.00000D+00	0.000
coulomb loss K+-	0.00000D+00	0.000
coulomb loss pbar	0.00000D+00	0.000
coulomb loss h-2	0.00000D+00	0.000
coulomb loss h-3	0.00000D+00	0.000
coulomb loss he-3	0.00000D+00	0.000
coulomb loss he-4	0.00000D+00	0.000
nuclear recoil	0.00000D+00	0.000
excitation	0.00000D+00	0.000
pi0 decay gammas	0.00000D+00	0.000
kin. eng. of e+,e-	0.00000D+00	0.000
positron mass	0.00000D+00	0.000
kin. eng. of muons	0.00000D+00	0.000
mu+ mass	0.00000D+00	0.000
mu- mass	0.00000D+00	0.000
total deposition	5.21322D-01	0.101

.
.
.
.
.

1 case no. 1 option no. 6

300 MeV Mass-Energy Deposition Audit 200 histories
12/27/99 CEASE - normal beam on front face with case

total energy deposition

	time total	
coulomb loss h-1	2.66593D+01	0.046
coulomb loss pi+-	0.00000D+00	0.000
coulomb loss mu+-	0.00000D+00	0.000
coulomb loss K+-	0.00000D+00	0.000
coulomb loss pbar	0.00000D+00	0.000
coulomb loss h-2	3.32249D-01	0.963
coulomb loss h-3	0.00000D+00	0.000
coulomb loss he-3	0.00000D+00	0.000
coulomb loss he-4	4.07842D-02	0.954
nuclear recoil	1.42414D-01	0.331
excitation	5.15510D-01	0.411
pi0 decay gammas	0.00000D+00	0.000

```
kin. eng. of e+,e-     0.00000D+00 0.000
positron mass          0.00000D+00 0.000
kin. eng. of muons     0.00000D+00 0.000
mu+ mass               0.00000D+00 0.000
mu- mass               0.00000D+00 0.000
total deposition       2.76903D+01 0.053

    case no.  1 completed

    execution time=  3.49 seconds
```

APPENDIX 3

MCNPX Input File

For

300 MeV Proton Beam Source Entering CEASE through Telescope Aperture

(cell and surface numbers refer to cells and surfaces shown in Figures 4 and 5, respectively)

```
Test for protons  CEASE Flight Sensor with Case for MCNPX
C
C   Proton, neutron, muon, pion, photon
C   transport - 300 MeV proton normal beam on top of case
C
C     Cells
C
c    begin collimator aperture
1    0    -1 29 -30
2    0    -2 30 -31
3    0    -3 31 -32
4    0    -4 32 -33
5    0    -5 33 -34
6    0    -6 34 -35
7    0    -7 35 -36
8    0    -8 36 -37
9    0    -9 37 -38
10   0   -10 38 -39
11   0   -11 39 -40
12   0   -12 40 -41
13   0   -13 41 -42
14   0   -14 42 -43
15   0   -15 43 -44
16   0   -16 44 -45
17   0   -17 45 -46
18   0   -18 46 -47
c    end of collimator aperture
c
c    copper collimator, cells 19-38
19   9 -8.92 -21  1 29 -30
20   9 -8.92 -21  2 30 -31
21   9 -8.92 -21  3 31 -32
22   9 -8.92 -21  4 32 -33
23   9 -8.92 -21  5 33 -34
24   9 -8.92 -21  6 34 -35
25   9 -8.92 -21  7 35 -36
26   9 -8.92 -21  8 36 -37
27   9 -8.92 -21  9 37 -38
28   9 -8.92 -21 10 38 -39
29   9 -8.92 -21 11 39 -40
30   9 -8.92 -21 12 40 -41
31   9 -8.92 -21 13 41 -42
32   9 -8.92 -21 14 42 -43
33   9 -8.92 -21 15 43 -44
34   9 -8.92 -21 16 44 -45
35   9 -8.92 -21 17 45 -46
36   9 -8.92 -21 18 46 -47
37   9 -8.92 -21 19 47 -48
38   9 -8.92 -21 19 48 -49
c    end of copper collimator
c
c    aluminum foil light shield
39   2 -2.7  -19 47 -48
c    tungsten collimator disk
40   3 -18.0 -19 20 48 -49
c    void annulus
41   0 -104 49 19 -51 #111 #112 #113 #114
c    void
42   0 -20 48 -49
c    gold annulus between tungsten and PCB
43   4 -18.88 -19 53 49 -51
c    void interior to gold annulus
44   0 -53 49 -51
c    void annulus space next to copper case
45   0 -104 89 -95 51
c    PCB annulus
46   2 -2.7 -89 53 51 -52 #111 #112 #113 #114
```

```
c    void space at center of PCB annulus
47   0 -53 51 -52
c    copper collimator section
48   9 -8.92 21 -22 29 -43
c    void annulus in collimator
49   0 21 -22 43 -49 #111 #112 #113 #114
c    copper case section
50   9 -8.92 22 -24 29 -106 #52 #53 #54 #55 #56 #57 #58 #59
c    copper case section
51   9 -8.92 49 -106 104 -22
c    stainless bolt
52   5 -8.0 29 -105 -25
c    stainless bolt
53   5 -8.0 29 -105 -26
c    stainless bolt
54   5 -8.0 29 -105 -27
c    stainless bolt
55   5 -8.0 29 -105 -28
c    stainless bolt tip
56   5 -8.0 105 -109
c    stainless bolt tip
57   5 -8.0 105 -110
c    stainless bolt tip
58   5 -8.0 105 -111
c    stainless bolt tip
59   5 -8.0 105 -112
c    void center of brass mounting for DFT
60   0 -55 52 -56
c    brass annulus mounting for DFT
61   1 -8.53 55 52 -59 -56
c    brass annulus mounting for DFT
62   1 -8.53 56 58 -59 -57
c    void center of brass mounting for DFT
63   0 56 -58 -57
c    void center of brass mounting for DFT
64   0 57 -58 -68
c    rubber mounting spacer for DFT
65   6 -7.4723 57 58 -61 -68
c    PMMA spacer for DFT
66   7 -1.19 57 -59 61 -68
c    DFT, electrically active part
67   8 -2.33 -67 68 -69
c    void
68   0 59 -89 52 -72 #111 #112 #113 #114
c    DFT, electrically inactive part
69   8 -2.33 67 -62 68 -69
c    PMMA spacer for DFT
70   7 -1.19 -59 68 62 -72
c    void space between DFT and brass mounting
71   0 69 -70 61 -62
c    rubber mounting spacer for DFT
72   6 -7.4723 69 -107 58 -61
c    void center below DFT
73   0 69 -71 -58
c    brass annulus mounting for DFT
74   1 -8.53 -107 70 -62 61
c    brass annulus mounting for DFT
75   1 -8.53 107 -71 58 -62
c    brass annulus mounting for DFT
76   1 -8.53 71 73 -72 -62
c    void center below DFT
77   0 -73 71 -72
c    PCB annulus
78   2 -2.7 75 72 -74 -89 #111 #112 #113 #114
c    void
79   0 59 -89 74 -85 #111 #112 #113 #114
c    void at center of PCB annulus
80   0 -75 72 -74
c    void at center of brass mounting for DBT
81   0 74 -77 -113
c    brass annulus mounting for DBT
82   1 -8.53 113 74 -77 -59
c    brass annulus mounting for DBT
83   1 -8.53 77 -78 76 -59
c    void at center of brass mounting for DBT
84   0 77 -79 -76
```

```
c    rubber spacer for DBT
85   6 -7.4723 78 -79 76 -108
c    PMMA spacer for DBT
86   7 -1.19 78 -79 108 -59
c    PMMA spacer for DBT
87   7 -1.19 79 -85 62 -59
c    DBT, electrically active part
88   8 -2.33 79 -81 -80
c    DBT, electrically inactive part
89   8 -2.33 79 -81 80 -62
c    void space between DBT and brass mounting
90   0 -62 81 -82 108
c    rubber spacer for DBT
91   6 -7.4723 81 -83 76 -108
c    void at center of brass mounting for DBT
92   0 81 -84 -76
c    brass annulus mounting for DBT
93   1 -8.53 82 -83 108 -62
c    brass annulus mounting for DBT
94   1 -8.53 83 -84 -62 76
c    brass annulus mounting for DBT
95   1 -8.53 84 -85 -62 86
c    void at center of brass mounting for DBT
96   0 84 -85 -86
c    void at center of PCB annulus
97   0 85 -87 -93
c    void annulus above PCB
98   0 88 85 -91 -89 #111 #112 #113 #114
c    gold spacer annulus on PCB
99   4 -18.88 85 -91 -88 87
c    PCB annulus
100  2 -2.7 -89 87 91 -92 #111 #112 #113 #114
c    void annulus below PCB
101  0 92 -93 -89 88 #111 #112 #113 #114
c    gold spacer annulus below PCB
102  4 -18.88 92 -93 -88 87
c    PMMA base annulus section
103  7 -1.19 59 -89 93 -101 #111 #112 #113 #114
c    PMMA base annulus section
104  7 -1.19 101 59 -89 -102 #115 #116 #117 #118
c    PMMA base annulus section
105  7 -1.19 59 -89 102 -94
c    PMMA base annulus section
106  7 -1.19 -59 93 90 -94
c    void at center of base PMMA annulus
107  0 -90 93 -94
c    void below PMMA annulus
108  0 94 -95 -89
c    copper case bottom
109  9 -8.92 95 -96 -104
c    copper case side/bottom
110  9 -8.92 106 -96 104 -24
c    PMMA rod
111  7 -1.19 103 -101 -63
c    PMMA rod
112  7 -1.19 103 -101 -64
c    PMMA rod
113  7 -1.19 103 -101 -65
c    PMMA rod
114  7 -1.19 103 -101 -66
c    PMMA rod
115  7 -1.19 101 -102 -97
c    PMMA rod
116  7 -1.19 101 -102 -98
c    PMMA rod
117  7 -1.19 101 -102 -99
c    PMMA rod
118  7 -1.19 101 -102 -100
c    outside case
c    aluminum top plate
119  2 -2.7 114 -29 117 -120 121 -124 #125 #139 #140 #141 #142
c    aluminum bottom plate
120  2 -2.7 115 -116 117 -120 121 -124 #139 #140 #141 #142
c    low x-side plate
121  2 -2.7 117 -118 29 -115 121 -124
```

```
c    high x-side plate
122  2 -2.7 119 -120 29 -115 121 -124
c    low y-side plate
123  2 -2.7 121 -122 29 -115 118 -119
c    high y-side plate
124  2 -2.7 123 -124 29 -115 118 -119
c    hole in case top to expose telescope aperture
125  0 114 -29 -1
c    micarta board
126  2 -2.7 96 -125  118 -119 122 -123 #142 #139 #140 #141
c    micarta board
127  2 -2.7 126 -127 118 -119 122 -123 #142 #139 #140 #141
c    micarta board
128  2 -2.7 128 -129 118 -119 122 -123 #142 #139 #140 #141
c    micarta board
129  2 -2.7 130 -131 118 -119 122 -123 #142 #139 #140 #141
c    micarta board
130  2 -2.7 132 -133 118 -119 122 -123 #142 #139 #140 #141
c    micarta board
131  2 -2.7 134 -135 118 -119 122 -123 #142 #139 #140 #141
c    void between top Al plate and top micarta board; excludes corner
c    bolts and telescope
132  0 29 -96 118 -119 122 -123 24 #139 #140 #141 #142
c    void between boards
133  0 125 -126 118 -119 122 -123
      #139 #140 #141 #142 #143 #149 #155 #161
c    void between boards
134  0 127 -128 118 -119 122 -123
      #139 #140 #141 #142 #144 #150 #156 #162
c    void between boards
135  0 129 -130 118 -119 122 -123
      #139 #140 #141 #142 #145 #151 #157 #163
c    void between boards
136  0 131 -132 118 -119 122 -123
      #139 #140 #141 #142
      #146 #152 #158 #164
c    void between boards
137  0 133 -134 118 -119 122 -123
      #139 #140 #141
      #142 #147 #153 #159  #165
c    void between boards
138  0 135 -115 118 -119 122 -123
      #139 #140 #141 #142 #148 #154 #160 #166
c    stainless corner bolt (case)
139  5 -8.0 -136 -116 114
c    stainless corner bolt (case)
140  5 -8.0 -137 -116 114
c    stainless corner bolt (case)
141  5 -8.0 -138 -116 114
c    stainless corner bolt (case)
142  5 -8.0 -139 -116 114
c
c    PMMA spacers(24) wrapped around stainless corner bolts
c    cells 143-166
143  7 -1.19 136 -140 #139 125 -126
144  7 -1.19 136 -140 #139 127 -128
145  7 -1.19 136 -140 #139 129 -130
146  7 -1.19 136 -140 #139 131 -132
147  7 -1.19 136 -140 #139 133 -134
148  7 -1.19 136 -140 #139 135 -115
149  7 -1.19 137 -141 #140 125 -126
150  7 -1.19 137 -141 #140 127 -128
151  7 -1.19 137 -141 #140 129 -130
152  7 -1.19 137 -141 #140 131 -132
153  7 -1.19 137 -141 #140 133 -134
154  7 -1.19 137 -141 #140 135 -115
155  7 -1.19 138 -142 #141 125 -126
156  7 -1.19 138 -142 #141 127 -128
157  7 -1.19 138 -142 #141 129 -130
158  7 -1.19 138 -142 #141 131 -132
159  7 -1.19 138 -142 #141 133 -134
160  7 -1.19 138 -142 #141 135 -115
161  7 -1.19 139 -143 #142 125 -126
162  7 -1.19 139 -143 #142 127 -128
163  7 -1.19 139 -143 #142 129 -130
164  7 -1.19 139 -143 #142 131 -132
```

```
166  7 -1.19 139 -143 #142 135 -115
c
c    exterior void region (1 cm thick ) above top z-plate
167  0 144 -114 146 -147 148 -149
c    exterior void region (1 cm thick ) below bottom z-plate
168  0 116 -145 146 -147 148 -149
c    exterior void region (1 cm thick ) outside lower x-plate
169  0 146 -117 148 -149 114 -116
c    exterior void region (1 cm thick ) outside upper x-plate
170  0 120 -147 148 -149 114 -116
c    exterior void region (1 cm thick ) outside lower y-plate
171  0 117 -120 148 -121 114 -116
c    exterior void region (1 cm thick ) outside upper y-plate
172  0 117 -120 124 -149 114 -116
c    escape region (extends to infinity in all directons)
173  0 -144:145:-148:149:-146:147

c      Surfaces
c
1      cz   0.5334
2      cz   0.5080
3      cz   0.4826
4      cz   0.4572
5      cz   0.4318
6      cz   0.4064
7      cz   0.3810
8      cz   0.3556
9      cz   0.3302
10     cz   0.3048
11     cz   0.2794
12     cz   0.2540
13     cz   0.2286
14     cz   0.2032
15     cz   0.1778
16     cz   0.1524
17     cz   0.1270
18     cz   0.1016
19     cz   0.4191
20     cz   0.02286
21     cz   0.750711
22     cz   1.06680
24     cz   1.5240
25     c/z  1.27  0.00 0.143111
26     c/z  0.00  1.27 0.143111
27     c/z -1.27  0.00 0.143111
28     c/z  0.00 -1.27 0.143111
29     pz   0.00000
30     pz   0.02540
31     pz   0.05080
32     pz   0.07620
33     pz   0.1016
34     pz   0.1270
35     pz   0.1524
36     pz   0.1778
37     pz   0.2032
38     pz   0.2286
39     pz   0.2540
40     pz   0.2794
41     pz   0.3048
42     pz   0.3302
43     pz   0.3556
44     pz   0.3810
45     pz   0.4064
46     pz   0.4318
47     pz   0.4572
48     pz   0.4581
49     pz   0.5080
51     pz   0.51652
52     pz   0.56732
53     cz   0.3111
55     kz   0.87842  1.0   -1
56     pz   0.592208
57     pz   0.64199
58     cz   0.28622
59     cz   0.8000
```

```
60    cz   0.6295
61    cz   0.34844
62    cz   0.73422
63    c/z  0.9087555  0.00  0.0248889
64    c/z  0.00  0.9087555  0.0248889
65    c/z -0.9087555  0.00  0.0248889
66    c/z  0.00 -0.9087555  0.0248889
67    cz   0.4021
68    pz   0.704212
69    pz   0.719212
70    pz   0.744212
71    pz   0.856101
72    pz   0.918323
73    kz   0.569883  1.0  +1
74    pz   0.969123
75    cz   0.423111
76    cz   0.373111
77    pz   1.019123
78    pz   1.043789
79    pz   1.113477
80    cz   0.518942
81    pz   1.163477
82    pz   1.203477
83    pz   1.243477
84    pz   1.293477
85    pz   1.352774
86    kz   0.920366  1.0  +1
87    cz   0.4064
88    cz   0.6096
89    cz   1.001777
90    cz   0.5080
91    pz   1.360394
92    pz   1.41119
93    pz   1.41881
94    pz   1.971965
95    pz   2.046631
96    pz   2.29552
97    c/z  0.9087555  0.00  0.0734222
98    c/z  0.00  0.9087555  0.0734222
99    c/z -0.9087555  0.00  0.0734222
100   c/z  0.00 -0.9087555  0.0734222
101   pz   1.518365
102   pz   1.953921
103   pz   0.448143
104   cz   1.027288
105   pz   1.142666
106   pz   1.29200
107   pz   0.787657
108   cz   0.43533
109   k/z  1.27  0.00  1.292  0.8575536  -1
110   k/z  0.00  1.27  1.292  0.8575536  -1
111   k/z -1.27 0.00   1.292  0.8575536  -1
112   k/z  0.00 -1.27  1.292  0.8575536  -1
113   kz   1.392234 1.0 -1
114   pz  -0.2032
115   pz   7.5565
116   pz   8.1661
117   px  -2.54
118   px  -2.3368
119   px   7.4168
120   px   7.62
121   py  -2.54
122   py  -2.3368
123   py   7.4168
124   py   7.62
125   pz   2.454275
126   pz   3.137535
127   pz   3.296285
128   pz   3.979545
129   pz   4.138295
130   pz   4.821555
131   pz   4.980305
132   pz   5.663565
133   pz   5.822315
134   pz   6.505575
135   pz   6.664325
136   c/z -1.79605   -1.79605  0.1058333
```

```
137   c/z  6.87605  -1.79605  0.1058333
138   c/z  6.87605   6.87605  0.1058333
139   c/z -1.79605   6.87605  0.1058333
140   c/z -1.79605  -1.79605  0.21167
141   c/z  6.87605  -1.79605  0.21167
142   c/z  6.87605   6.87605  0.21167
143   c/z -1.79605   6.87605  0.21167
144    pz -1.2032
145    pz  9.166
146    px -3.54
147    px  8.62
148    py -3.54
149    py  8.62
C
c      Transport protons, neutrons, muons, photons, pions

mode    h n | p /
c   Source definition, proton source (par=9), located on surface
c   #114 which is the plane at z=-0.2032, centered at 0.,0.-,0.2032,
c   with radius 1.4 cm, energy 300 MeV,Normal incidence (along z)
SDEF     sur=114 pos=0. 0. -.2032  rad=D1 ERG=300.  WGT=1.0  DIR=1 par=9
SI1  .25
VOL   45J 0.144715 3J 4.501818 27J 0.1311943 21J 0.1333961
      2J 0.1129316 0.4679637  14J 19.61581 61.74832 5J
      139.2479  139.2432  103.1126 103.1126 103.1126
      103.1126  42J
c     No. of histories
NPS   1000
C
C   Materials
C
C       Brass
M1      29000 -.3  28000  -.7
C       Aluminum
M2      13027 -1.0
C       Tungsten
M3      74000 -.95 29000 -.015  28000 -.035
C       Gold
M4      79197 -1.0
C       Stainless Steel
M5      26000 -.71 29000 -.17 25055 -.065 28000 -.005 14000 -.05
C       Conductive Silicone Elastomer
M6      28000 -.377 47000 -.373 14000 -.0947
         6000 -.0810  8016 -.0539  1001 -.0204
C       PMMA
M7       6000 -.59985  8016 -.31961 1001 -.080538
C       Silicon
M8      14000 -1.0
C       Copper
M9      29000 -1.0
c    maximum proton energy(MeV) required for cross section table
PHYS:h 400.
c    maximum neutron energy(MeV) required for cross section table
PHYS:n 400.
c    maximum muon energy(MeV) required for cross section table
PHYS:| 400.
c    maximum photon energy(MeV) required for cross section table
PHYS:p 400.
c    maximum pion energy(MeV) required for cross section table
PHYS:/ 400.
c    Tallies
c  F46:p, F56:p, F66:p, F76:p, F86:p are photon track length
c     energy deposition (heating) tallies (MeV/gm)
F46:p    19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
F56:p    36 37 38 39 40 43  46 48  50 51  52 53 54 55 56 57 58
F66:p    59 61 62 65 66 67 70 72 74 75 76 78 82 83 85 86 87
F76:p   88 89 91 93 94 95 99 100  102 103 104 105 106 109
```

```
F86:p    110 111 112 113 114 115 116 117 118 119 120 121 122 123 124
         126 127 128 129 139 131 139 140 141 142 143 144 145 146 147
         148 149  150 151 152 153 154 155 156 157 158 159 160 161
         162 163 164 165 166
c + F6:n,p,h, etc are proton energy deposition tallies
+F6:n,p     19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
+F16:n,p     36 37 38 39 40 43 46 48 50 51  52 53 54 55 56 57 58
+F26:n,p     59 61 62 65 66 67 70 72 74 75 76 78 82 83 85 86 87
+F36:n,p    88 89 91 93 94 95 99 100 102 103 104 105 106 109
+F106:n,p 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124
           126 127 128 129 130 131
         139 140 141 142 143 144 145 146 147 148 149
         150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165
         166
c     charge deposition tallies
+F98:h     19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
+F58:h     36 37 38 39 40 43 46  48  50 51 52 53 54 55 56 57 58
+F68:h     59 61 62 65 66 67 70 72 74 75 76 78 82 83 85 86 87
+F78:h   88 89 91 93 94 95 99 100 102  103 104 105 106 109
+F88:h    110 111 112 113 114 115 116 117 118 119 120 121 122 123 124
           126 127 128 129 130 131
         139 140 141 142 143 144 145 146 147
         148 149 150 151 152 153 154 155 156 157 158 159 160 161 162
         163 164 165 166
c     proton flux tallies
F44:h    19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
F54:h     36 37 38 39 40 43 46 48 50 51  52 53 54 55 56 57 58
F64:h     59 61 62 65 66 67 70 72 74 75 76 78 82 83 85 86 87
F74:h    88 89 91 93 94 95 99 100 102 103 104 105 106 109
F84:h    110 111 112 113 114 115 116 117 118 119 120 121 122 123 124
         126 127 128 129 130 131
         139 140 141 142 143 144 145 146 147 148 149
         150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165
         166
c     neutron flux tallies
F144:n    19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
F154:n     36 37 38 39 40 43 46 48 51 50 52 53 54 55 56 57 58
F164:n     59 61 62 65 66 67 70 72 74 75 76 78 82 83 85 86 87
F174:n    88 89 91 93 94 95 99 100 102 103 104 105 106 109
F184:n    110 111 112 113 114 115 116 117 118 119 120 121 122 123 124
         126 127 128 129 130 131
         139 140 141 142 143 144 145 146 147 148 149
         150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165
         166
c   proton energy flux tallies
*F104:h    19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
*F114:h     36 37 38 39 40 43 46 48 51 50 52 53 54 55 56 57 58
*F124:h     59 61 62 65 66 67 70 72 74 75 76 78 82 83 85 86 87
*F134:h    88 89 91 93 94 95 99 100 102 103 104 105 106 109
*F94:h    110 111 112 113 114 115 116 117 118 119 120 121 122 123 124
         126 127 128 129 130 131
         139 140 141 142 143 144 145 146 147 148 149
         150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165
         166
c     cell importances for protons
imp:h   1  165R   0 6R
c     cell importances for photons
imp:p   1  165R   0 6R
c     cell importances for neutrons
imp:n   1  165R   0 6R
c     cell importances for muons
imp:|   1  165R   0 6R
c     cell importances for pions
imp:/   1  165R   0 6R
ptrac  write=all   file=asc
```

APPENDIX 4
MCNPX Input File
For
150 MeV Proton Source Entering HEP through Side of Aluminum Case
(see Figure 9(b), surface #145).
3.0 cm Radius Disk Source; Isotropic Incidence.

```
Test for protons  HEP in- flight version for MCNPX
C
C   Proton, neutron, muon, pion, photon
C   transport - 150 MeV protons isotropic angular dist on x face of box
C
C     Cells
C
c    collimator
1    0  1 -3 -7
c    Tungsten P17
2    3 -18.0  1 -3 -5 #1
c    Tungsten P17
3    3 -18.0  1 -2 5 -4
c    Copper P16
4    9  -8.92 2 -8 5 -6
c    Copper P16
5    9  -8.92 8 -3 5 -4
c    Copper P16
6    9  -8.92 3 -9 -4
c    Plastic  Kel-F  P4
7    13  -2.2  9 -10 -4
c    Phosphor Bronze P9
8    1  -8.89 10 -13 14 -12
c    void  P9
9    0  10 -13 -14
c         Plastic  Kel-F  P4
10   13  -2.2 10 -11 -4 12
c         Plastic  Kel-F  P8
11   13  -2.2 13 -15 -12 18
c         Plastic  Kel-F  P4
12   13  -2.2 11 12 -16 -4
c    Phosphor Bronze P9
13   1  -8.89 15 -16 14 -12
c    void  P9
14   0  15 -16 -14
c       Plastic  Kel-F  P4
15   13  -2.2 16 -17 -4
c
c    D1 assembly starts here
c    PCB Ring mount
16   2  -2.7 13 -20 -18 24
c    PCB Ring mount
17   2  -2.7 20 -19 -21 24
c    PCB Ring mount
18   2  -2.7 21 -23 -19 24
c    PCB Ring mount
19   2  -2.7 23 24 -18 -15
20   0   13 -21 -30
21   0   21 -22 -29
c    PCB Ring mount
22   2  -2.7 13 -21 -24 #20
23   0   21 -22 -24 28
c    Rubber wafer mount
24   6  -7.47  29 -28 -22 21
c    Oxide ring
25   11  -2.32 29 -25 22 -23
c    Aluminum coating on Si wafer
26   2  -2.7   22 -23 -29
c    Silicon wafer
27   8  -2.33   23 -26 -25
c    Aluminum coating on Si wafer
```

```
28    2  -2.7    26 -27 -25
29    0     22 -15 -24 #25 #26 #27 #28
30    0     19 20 -18 -23
c
c     end of D1 assembly
c
c        Plastic  Kel-F  P4
31    13  -2.2    17 -31 -4
c     Phosphor Bronze P9
32    1  -8.89    31 -32 -12 14
33    0     31 -32 -14
c          Plastic  Kel-F  P4
34    13  -2.2    31 -33 12 -4
c          Plastic  Kel-F  P5
35    13  -2.2    33 12 -4 -35
c     Plastic  Kel-F  P8
36    13  -2.2    32 -12 18 -34
c     Phosphor Bronze P9
37    1  -8.89    34 -35 -12 14
38    0     34 -35 -14
c     Plastic  Kel-F  P5
39    13  -2.2    35 -36 -4
c
c     D2 assembly starts here
c
c     PCB Ring mount
40    2 -2.7 32 -37 -18 24
c     PCB Ring mount
41    2 -2.7 37 -19 -39 24
c     PCB Ring mount
42    2 -2.7 39 -38 -19 24
c     PCB Ring mount
43    2 -2.7 38 24 -18 -34
44    0  32 -39 -41
45    0  39 -40 -29
c     PCB Ring mount
46    2 -2.7 32 -39 -24 #44
47    0    39 -40 -24 28
c     Rubber wafer mount
48    6  -7.47  29 -28 -40 39
c     Oxide ring
49    11  -2.32 29 -25 40 -38
c     Aluminum coating on Si wafer
50    2  -2.7    40 -38 -29
c     Silicon wafer
51    8  -2.33    38 -42 -25
c     Aluminum coating on Si wafer
52    2  -2.7    42 -43 -25
53    0     40 -34 -24 #49 #50 #51 #52
54    0     19 -18 37 -38
c
c     end of D2 assembly
c
c     start of S1, S3 assembly
c
c     Plastic  Kel-F  P5
55    13  -2.2     36 -44 -45 46
c     Plastic  Kel-F  P5
56    13  -2.2     36 -44 -47
c     Spectralon  P13, P14 with rectangular cut (cell 122)
57    12  -2.2     36 -49 45 -4 #122 #123
c     Spectralon P10, P11 with rectangular cut (cell 121)
58    12  -2.2     36 -49 47 -46  #121 #119
c     Scintillator - S3 with rectangular cut and pin diode (cells 123, 124)
59    4   -1.03    44 -48 46 -45 #123 #124
c     GSO   S1 with pin diode on flat (cells 119, 120)
60    10  -7.05    44 -48 -47 #119 #120
c     Plastic  Kel-F  P5
61    13  -2.2     48 -49 46 -45
c     Plastic  Kel-F  P5
62    13  -2.2     48 -49 -47
c     Plastic  Kel-F  P5
63    13  -2.2     49 -50 -4
c     end of S3, S1 assembly
c
```

```
c     Phosphor Bronze  P9B
64    1  -8.89     50 -51 -12
c     Plastic  Kel-F  P5
65    13  -2.2     50 -52 12 -4
c     Plastic  Kel-F  P6
66    13  -2.2     52 -54 12 -4
c     Phosphor Bronze  P9B
67    1  -8.89     53 -54 -12
c     Plastic  Kel-F  P6
68    13  -2.2     54 -55 -4
c     Plastic  Kel-F  P6
69    13  -2.2     55 -56 -57
c     Plastic  Kel-F  P7
70    13  -2.2     51 -53 58 -12
c
c     start D3 assembly
c     void
71    0 51 -59 -66
c     void
72    0 59 -60 -68
c     PCB annulus
73    2  -2.7    51 -60 -58 #71 #72
c     PMMA
74    7  -1.19   60 -61 70 -58
c     PMMA
75    7  -1.19   57 -58 61 -53
c     void
76    0       60 -61 -69
c     Si wafer - electrically active part
77    8  -2.33      61 -62 -70
c     Si wafer - electrically inactive part
78    8  -2.33      70 -57 61 -62
c     void
79    0 62 -63 70 -57
c     rubber mounting spacer
80    6  -7.47     69 -70 60 -61
c     rubber mounting spacer
81    6  -7.47     69 -70 62 -64
c     PCB annulus
82    2  -2.7    63 -64 70 -57
c     PCB annulus
83    2  -2.7    64 -53 -57 #85 #86
c     void
84    0 62 -64 -69
c     void
85    0 64 -65 -68
c     void
86    0 65 -53 -67
c     end D3 assembly
c
c     begin S2 assembly
c     GSO  S2
87    10  -7.05  56 -57 -71 #125 #126 #127
c     Spectralon P12
88    12  -2.2      55 -72 57 -4 #128 #129 #130 #131
c     Plastic  Kel-F  P6
89    13  -2.2      71 -72 -57
c     Plastic  Kel-F  P6
90    13  -2.2      72 -73 -4
c     Plastic  Kel-F  P6
91    13  -2.2      73 -75 12 -4
c     phosphor bronze  P9B
92    1   -8.89     73 -74 -12
c     Plastic  Kel-F  P4
93    13  -2.2      12 -4 75 -77
c     phosphor bronze  P9B
94    1  -8.89      76 -77 -12
c     Plastic  Kel-F  P4
95    13  -2.2      77 -78 -4
c     end S2 assembly
c
c     begin D4 assembly
c     void
96    0 74 -79 -86
c     void
97    0 79 -80 -88
```

```
c    PCB  annulus
98   2  -2.7     88 74 -80 -12 #96 #97
c    PMMA
99   7  -1.19    80 -81 90 -12
c    PMMA
100  7  -1.19    91 -12 81 -76
c    void
101  0 80 -81 -89
c    Si wafer - electrically active epart
102  8 -2.33     81 -82 -90
c    Si wafer - electrically inactive part
103  8  -2.33    81 -82 90 -91
c    void
104  0   82 -83 90 -91
c    rubber mounting spacer
105  6  -7.47    80 -81 89 -90
c    rubber mounting spacer
106  6  -7.47    82 -84 89 -90
c    PCB annulus
107  2  -2.7    90 -91 83 -84
c    PCB annulus
108  2  -2.7    84 -91 -76 #110 #111
c    void
109  0    82 -84 -89
c    void
110  0    84 -85 -88
c    void
111  0    85 -76 -87
c    end of D4 assembly
c
c    Aluminum  P18
112  2  -2.7   78 -92 -4 98
c    Aluminum  P18
113  2  -2.7   92 -94 93 -4
c    Copper base  P15
114  9  -8.92    92 -94 -93
c    Copper base  P15
115  9  -8.92    94 -95 -6
c    Copper case cylinder
116  9  -8.92    8  4 -94 -6  #132  #133
c    Stainless bulkhead
117  5  -8.0     95 -96 -97 #149
c    void
118  0    78 -92 -98
c
c    pin diode mounted on S1 flat
119  8 -2.33 99 -100  103 -104 113 -114
c    flat slot on S1 for diode
120  0          99 -47 44 -105 #119
c    rectangular cut in P10,P11 assembly
c    plane 99 is used as the ambiguity surface
121  0            47 -46 36 -105 113 -114 99 #119
c    rectangular cut in P13,P14 assembly
c    plane 108 is used as the ambiguity surface
122  0            45 -4 106 -107 101 -102  108 #123
c
c    pin diode mounted on S3 flat
123  8 -2.33 108 -109 110 -111 101 -102
c    flat slot on S3 for diode
124  0  108 -45 106 -107 #123
c
c    PIN diode mounted on S2 flat (portion carved out of S2)
125  8 -2.33  115 -57  118 -119
c    void cells carved out of S2
126  0  56 115 -118 -57
127  0 119 115 -117 -57
c    void cells carved out of P12 bushing
128  0 56 -118 57 -116 99
129  0 119 -117 57 -116 99
130  8 -2.33 118 -119 115 -116 101 -102  #125
c    rectangular cut in P12
131  0  56 -117 116 -4 101 -102 99
c
c     flat on copper case to accommodate copper pin shield
132  0 120 -94 121 -6  #134
c     slot in copper case (99 is ambiguity surface)
```

```
133   0    4 -121 8 -92 99 122 -123
c      copper pin shield
134   9   -8.92 121 -124 125 -126 120 -127 #135 #136 #137 #138 #139 #140
          #141 #142 #143 #144 #145 #146 #147 #148
c      pin holes in copper pin shield
135   0   121 -124 -128
136   0   121 -124 -129
137   0   121 -124 -130
138   0   121 -124 -131
139   0   121 -124 -132
140   0   121 -124 -133
141   0   121 -124 -134
142   0   121 -124 -135
143   0   121 -124 -136
144   0   121 -124 -137
145   0   121 -124 -138
146   0   121 -124 -139
147   0   121 -124 -140
148   0   121 -124 -141
c
c     flat bite out of the stainless  bulkhead
149   0   -142  95 -96 -97
c
c     Aluminum box
c     back plate perp. to z (0.1" thick)
150   2 -2.7 143 -95 144 -148 146 -147 #115
c     front plate perp. to z (0.1" thick)
151   2 -2.7 1 -2 144 -148 146 -147 #1 #2 #3
c     top plate perp. to x (0.1" thick)
152   2 -2.7 1 -95 148 -145 146 -147
c     bottom plate perp. to x (0.25" thick)
153   2 -2.7 1 -95 144 -149 146 -147
c     upper side plate perp. to y (0.1" thick) sits on bottom x-plate
c     and buts inside top x-plate, and buts inside both z-plates
154   2 -2.7 2 -143 149 -148 150 -147 #156
c     lower side plate perp. to y (0.1" thick) sits on bottom x-plate
c     and buts inside top x-plate, and buts inside both z-plates
155   2 -2.7 2 -143 149 -148 -151 146 #157
c     large connector hole (rectangular) in upper y plate
156   0   150 -147 152 -153  154 -155
c     small connector hole (rectangular) in lower y plate
157   0   146 -151 156 -157  158 -159
c     exterior void outside lower z plate (1 cm thick)
158   0   -1 160 144 -145 146 -147
c     exterior void outside upper z plate (1 cm thick)
159   0   95 -96 97  -145 146 -147 99
160   0   96 -161 144 -145 146 -147
c     exterior void outside lower x plate (1 cm thick)
161   0   162 -144 160  -95 146 -147 -99
162   0 97 95 -96 162 146 -147 -99
163   0 -144 96 162 -161 146 -147
c     exterior void outside upper x plate (1 cm thick)
164   0   -163 145 160  -161 146 -147
c     exterior void outside lower y plate (1 cm thick)
165   0   164 -146 160  -161 162 -163
c     exterior void outside upper y plate (1 cm thick)
166   0   147 -165 160  -161 162 -163
c     void region inside box, excluding hep instrument
167   0 2 -143 149 -148 151 -150 6
c     exterior void escape region
168   0     -160:161:-162:163:-164:165

c       Surfaces
c
1       pz  0.0
2       pz  0.254
3       pz  1.4351
4       cz  1.58877
5       cz  0.8001
6       cz  2.0955
7       kz  3.2802 0.034537 -1
8       pz  0.508
9       pz  1.552
10      pz  1.6027
11      pz  1.7932
12      cz  1.4351
```

```
13    pz  1.61544
14    cz  0.47625
15    pz  1.98374
16    pz  1.99644
17    pz  2.03454
18    cz  0.6985
19    cz  0.635
20    pz  1.69672
21    pz  1.76340
22    pz  1.78940
23    pz  1.79741
24    cz  0.5
25    cz  0.482
26    pz  1.8314
27    pz  1.8394
28    cz  0.3
29    cz  0.28209
30    kz  1.95495 2.168864 -1
31    pz  2.08534
32    pz  2.09804
33    pz  2.27584
34    pz  2.46634
35    pz  2.47904
36    pz  2.5298
37    pz  2.1793
38    pz  2.28
39    pz  2.2460
40    pz  2.2720
41    kz  2.4375 2.168864 -1
42    pz  2.3140
43    pz  2.32202
44    pz  2.58064
45    cz  1.45415
46    cz  0.94615
47    cz  0.75057
48    pz  5.58038
49    pz  5.63118
50    pz  5.68198
51    pz  5.69468
52    pz  5.89788
53    pz  6.10108
54    pz  6.11378
55    pz  6.16466
56    pz  6.21538
57    cz  1.0
58    cz  1.105
59    pz  5.7221
60    pz  5.7495
61    pz  5.83133
62    pz  5.90194
63    pz  5.9195
64    pz  5.97256
65    pz  6.01243
66    kz  6.43183 0.945216 -1
67    kz  4.86572 0.3620646 +1
68    cz  0.69
69    cz  0.74334
70    cz  0.82335
71    pz  8.21436
72    pz  8.26516
73    pz  8.31596
74    pz  8.32866
75    pz  8.53186
76    pz  8.73506
77    pz  8.74776
78    pz  8.79856
79    pz  8.35609
80    pz  8.38352
81    pz  8.46531
82    pz  8.53592
83    pz  8.55345
84    pz  8.60654
85    pz  8.64641
86    kz  9.35914  .944856  -1
87    kz  7.02605  .362067  +1
88    cz  0.975
```

```
89      cz  1.02834
90      cz  1.10835
91      cz  1.32319
92      pz  8.86460
93      cz  1.27
94      pz  9.1694
95      pz  10.16
96      pz  10.47750
97      cz  2.921
98      cz  0.9525
99      px  0.4788
100     px  0.6574
101     py -0.635
102     py  0.635
103     pz  2.61874
104     pz  4.0665
105     pz  4.10464
106     pz  3.342464
107     pz '4.86664
108     px  1.18237
109     px  1.36097
110     pz  3.380564
111     pz  4.82854
c       surface 112 no longer used
c       112     pz -0.1
113     py   -0.5780189
114     py    0.5780189
115     px   .94615
116     px   1.12475
117     pz   7.73938
118     pz   6.25348
119     pz   7.70128
120     pz   1.1684
121     px   1.8415
122     py   -.1143
123     py    .1143
124     px   2.0955
125     py   -0.9525
126     py    0.9525
127     pz    9.1059
128     c/x   0.    1.6764    0.08
129     c/x   0.    1.9304    0.08
130     c/x   0.    2.21488   0.08
131     c/x   0.    2.46888   0.08
132     c/x   0.    3.01752   0.08
133     c/x   0.    3.27152   0.08
134     c/x   0.    4.21386   0.08
135     c/x   0.    4.46786   0.08
136     c/x   0.    5.88010   0.08
137     c/x   0.    6.13410   0.08
138     c/x   0.    7.01294   0.08
139     c/x   0.    7.26694   0.08
140     c/x   0.    8.54456   0.08
141     c/x   0.    8.79956   0.08
142     px    -2.667
143     pz   9.906
144     px   -2.794
145     px   4.318
146     py   -3.9624
147     py    3.9624
148     px    4.064
149     px   -2.159
150     py   3.7084
151     py   -3.7084
152     pz   1.508125
153     pz   8.611575
154     px   -1.524
155     px    -.016
156     px   -1.5748
157     px   -.9398
158     pz    3.889375
159     pz    6.270625
160     pz   -1.0
161     pz    11.16
162     px   -3.794
163     px    5.318
```

```
164     py  -4.9624
165     py   4.9624
C
c       Transport protons

mode    h
c   Source definition, proton source (par=9), located on surface
c   #145 which is the plane at X=4.318,
c   with radius 3.0 cm, energy 150 MeV,ISOTROPIC incidence
SDEF     sur=145 pos=4.318 0. 5.08 NRM=-1 rad=D1 ERG=150.  WGT=1.0 par=9
SI1  3.0
VOL    56J 3.805344 3.060979  10.92574 4.976314 21J 0.01776879
       4J 6.244362  9.046072 27J 40.73179 8.381271
       7J 0.03383785   4J 0.2945550 3J 3.769220
       15J 10.81179  9.926189  17J
c      No. of histories
NPS  1000
C
C         Materials
C
C        Phosphor Bronze
M1       29000 -.9865  50000  -0.0125  15031  -0.001
C        Aluminum
M2       13027 -1.0
C        Tungsten
M3       74000 -.95 29000 -.015  28000 -.035
C        Plastic Scintillator
M4       6000  -0.9205  1001  -0.0795
C        Stainless Steel
M5       26000 -.71 29000 -.17 25055 -.065 28000 -.005 14000 -.05
C        Conductive Silicone Elastomer
M6       28000 -.377 47000 -.373 14000 -.0947
          6000 -.0810  8016 -.0539  1001 -.0204
C        PMMA
M7        6000 -.59985  8016 -.31961 1001 -.080538
C        Silicon
M8       14000 -1.0
C        Copper
M9       29000 -1.0
C
C        GSO
M10      64000  -0.74259  14000  -0.066889  8016  -0.190521
C
C        Silicon Dioxide
M11      14000  -0.467435  8016  -0.532565
C
C        Spectralon (Teflon  C2F4)
M12      6000  -0.240183  9019  -0.759817
C
C        Kel-F  (chlorotrifluoroethylene  C2ClF3)
M13      6000  -0.20625  17000  -0.30440  9019  -0.48935
c
c
c    maximum proton energy(MeV) required for cross section table
PHYS:h 300.
c
c    Tallies
F1:h   2 3 4
c    cell importances for protons
imp:h   1  166R   0
```

APPENDIX 5

ITS-ACCEPT Input File for CEASE Telescope with Frame and Case

(source is a normally incident beam of 9.9 MeV electrons, uniformly distributed over a disk of radius 1.4 cm, positioned directly above the telescope behind the front face of the case – body, cell labels, excepting frame and case, correspond to those shown in Figures 12, 13, resp.)

```
TITLE
  9.9 MEV CEASE TEST PROBLEM FRONT ENTRY, NORMAL INCIDENCE
********************** GEOMETRY ***********************
GEOMETRY 1
*1
  RCC   0.0   0.0   0.0       0.0   0.00000  0.02540   0.5334
*2
  RCC   0.0   0.0   0.02540   0.0   0.00000  0.02540   0.5080
*3
  RCC   0.0   0.0   0.05080   0.0   0.00000  0.02540   0.4826
*4
  RCC   0.0   0.0   0.07620   0.0   0.00000  0.02540   0.4572
*5
  RCC   0.0   0.0   0.10160   0.0   0.00000  0.02540   0.4318
*6
  RCC   0.0   0.0   0.12700   0.0   0.00000  0.02540   0.4064
*7
  RCC   0.0   0.0   0.15240   0.0   0.00000  0.02540   0.3810
*8
  RCC   0.0   0.0   0.17780   0.0   0.00000  0.02540   0.3556
*9
  RCC   0.0   0.0   0.20320   0.0   0.00000  0.02540   0.3302
*10
  RCC   0.0   0.0   0.22860   0.0   0.00000  0.02540   0.3048
*11
  RCC   0.0   0.0   0.25400   0.0   0.00000  0.02540   0.2794
*12
  RCC   0.0   0.0   0.27940   0.0   0.00000  0.02540   0.2540
*13
  RCC   0.0   0.0   0.30480   0.0   0.00000  0.02540   0.2286
*14
  RCC   0.0   0.0   0.33020   0.0   0.00000  0.02540   0.2032
*15
  RCC   0.0   0.0   0.35560   0.0   0.00000  0.02540   0.1778
*16
  RCC   0.0   0.0   0.38100   0.0   0.00000  0.02540   0.1524
*17
  RCC   0.0   0.0   0.40640   0.0   0.00000  0.02540   0.1270
*18
  RCC   0.0   0.0   0.43180   0.0   0.00000  0.02540   0.1016
*19
  RCC   0.0   0.0   0.0       0.0   0.0      0.02540   0.750711
*20
  RCC   0.0   0.0   0.02540   0.0   0.0      0.02540   0.750711
*21
  RCC   0.0   0.0   0.05080   0.0   0.00000  0.02540   0.750711
*22
  RCC   0.0   0.0   0.07620   0.0   0.00000  0.02540   0.750711
*23
  RCC   0.0   0.0   0.10160   0.0   0.00000  0.02540   0.750711
*24
  RCC   0.0   0.0   0.12700   0.0   0.00000  0.02540   0.750711
*25
  RCC   0.0   0.0   0.15240   0.0   0.00000  0.02540   0.750711
*26
  RCC   0.0   0.0   0.17780   0.0   0.00000  0.02540   0.750711
*27
  RCC   0.0   0.0   0.20320   0.0   0.00000  0.02540   0.750711
*28
  RCC   0.0   0.0   0.22860   0.0   0.00000  0.02540   0.750711
*29
  RCC   0.0   0.0   0.25400   0.0   0.00000  0.02540   0.750711
*30
  RCC   0.0   0.0   0.27940   0.0   0.00000  0.02540   0.750711
*31
  RCC   0.0   0.0   0.30480   0.0   0.00000  0.02540   0.750711
*32
```

```
 RCC   0.0    0.0    0.33020    0.0    0.00000  0.02540    0.750711
*33
 RCC   0.0    0.0    0.35560    0.0    0.00000  0.02540    0.750711
*34
 RCC   0.0    0.0    0.38100    0.0    0.00000  0.02540    0.750711
*35
 RCC   0.0    0.0    0.40640    0.0    0.00000  0.02540    0.750711
*36
 RCC   0.0    0.0    0.43180    0.0    0.00000  0.02540    0.750711
*37
 RCC   0.0    0.0    0.45720    0.0    0.00000  0.00090    0.750711
*38
 RCC   0.0    0.0    0.45810    0.0    0.00000  0.04990    0.750711
*39
 RCC   0.0    0.0    0.45720    0.0    0.00000  0.00090    0.4191
*40
 RCC   0.0    0.0    0.45810    0.0    0.00000  0.04990    0.4191
*41
 RCC   0.0    0.0    0.45810    0.0    0.00000  0.04990    0.02286
*42
 RCC   0.0    0.0    0.0        0.0    0.00000  0.3556     1.06680
*43
 RCC   0.0    0.0    0.3556     0.0    0.0      0.1524     1.06880
*44
 RCC   0.9087555  0.0  0.448143    0.0    0.0    0.059857  0.0248889
*45
 RCC   0.0 0.9087555    0.448143    0.0    0.0    0.059857  0.0248889
*46
 RCC   -0.9087555  0.0  0.448143    0.0    0.0    0.059857  0.0248889
*47
 RCC   0.0 -0.9087555    0.448143    0.0    0.0    0.059857  0.0248889
*48
 RCC   1.27  0.0  0.0  0.0  0.0  1.142666  0.143111
*49
 RCC   0.0  1.27  0.0  0.0  0.0  1.142666  0.143111
*50
 RCC   -1.27  0.0  0.0  0.0  0.0  1.142666  0.143111
*51
 RCC   0.0  -1.27  0.0  0.0  0.0  1.142666  0.143111
*52
 TRC  1.27  0.0  1.142666  0.0  0.0  0.149334  0.143111  0.0001
*53
 TRC  0.0  1.27  1.142666  0.0  0.0  0.149334  0.143111  0.0001
*54
 TRC  -1.27  0.0  1.142666  0.0  0.0  0.149334  0.143111  0.0001
*55
 TRC  0.0  -1.27  1.142666  0.0  0.0  0.149334  0.143111  0.0001
*56
 RCC  0.0  0.0  0.5080  0.0  0.0  0.00852  0.3111
*57
 RCC  0.0  0.0  0.5080  0.0  0.0  0.00852  0.4191
*58
 RCC  0.0  0.0  0.5080  0.0  0.0  0.00852  1.027288
*59
 RCC   0.9087555  0.0  0.5080    0.0    0.0    0.00852  0.0248889
*60
 RCC   0.0 0.9087555    0.5080    0.0    0.0    0.00852  0.0248889
*61
 RCC   -0.9087555  0.0  0.5080    0.0    0.0    0.00852  0.0248889
*62
 RCC   0.0 -0.9087555    0.5080    0.0    0.0    0.00852  0.0248889
*63
 RCC  0.0  0.0  0.51652  0.0  0.0  0.05080  0.3111
*64
 RCC   0.9087555  0.0  0.51562    0.0    0.0    0.05080  0.0248889
*65
 RCC   0.0 0.9087555    0.51562    0.0    0.0    0.05080  0.0248889
*66
 RCC   -0.9087555  0.0  0.51562    0.0    0.0    0.05080  0.0248889
*67
 RCC   0.0 -0.9087555    0.51562    0.0    0.0    0.05080  0.0248889
*68
 RCC  0.0  0.0  0.51652  0.0  0.0  0.05080  1.0017
*69
 RCC  0.0  0.0  0.51652  0.0  0.0  0.05080  1.027288
*70
 TRC  0.0  0.0  0.56732  0.0  0.0  0.024888  0.3111  0.28622
*71
 RCC  0.0  0.0  0.56732  0.0  0.0  0.024888  0.8
*72
```

```
 RCC  0.0  0.0  0.56732  0.0  0.0  0.024888  1.027288
*73
 RCC   0.9087555  0.0  0.56732   0.0   0.0   0.024888  0.0248889
*74
 RCC   0.0 0.9087555   0.56732   0.0   0.0   0.024888  0.0248889
*75
 RCC   -0.9087555  0.0  0.56732  0.0   0.0   0.024888  0.0248889
*76
 RCC   0.0 -0.9087555   0.56732  0.0   0.0   0.024888  0.0248889
*77
 RCC  0.0  0.0  0.592208  0.0  0.0  0.049782  0.28622
*78
 RCC  0.0  0.0  0.592208  0.0  0.0  0.049782  0.8
*79
 RCC  0.0  0.0  0.592208  0.0  0.0  0.049782  1.027288
*80
 RCC   0.9087555  0.0  0.592208   0.0   0.0   0.049782  0.0248889
*81
 RCC   0.0 0.9087555   0.592208   0.0   0.0   0.049782  0.0248889
*82
 RCC   -0.9087555  0.0  0.592208   0.0   0.0   0.049782  0.0248889
*83
 RCC   0.0 -0.9087555   0.592208   0.0   0.0   0.049782  0.0248889
*84
 RCC  0.0  0.0  0.64199   0.0  0.0  0.062222  0.28622
*85
 RCC  0.0  0.0  0.64199   0.0  0.0  0.062222  0.34844
*86
 RCC  0.0  0.0  0.64199   0.0  0.0  0.062222  0.8
*87
 RCC  0.0  0.0  0.64199   0.0  0.0  0.062222  1.027288
*88
 RCC   0.9087555  0.0  0.64199   0.0   0.0   0.062222  0.0248889
*89
 RCC   0.0 0.9087555   0.64199   0.0   0.0   0.062222  0.0248889
*90
 RCC   -0.9087555  0.0  0.64199   0.0   0.0   0.062222  0.0248889
*91
 RCC   0.0 -0.9087555   0.64199   0.0   0.0   0.062222  0.0248889
*92
 RCC  0.0  0.0  0.704212   0.0  0.0  0.015  0.4021
*93
 RCC  0.0  0.0  0.704212   0.0  0.0  0.015  0.73422
*94
 RCC  0.0  0.0  0.704212   0.0  0.0  0.015  0.8
*95
 RCC  0.0  0.0  0.704212   0.0  0.0  0.015  1.027288
*96
 RCC   0.9087555  0.0  0.704212   0.0   0.0   0.015  0.0248889
*97
 RCC   0.0 0.9087555   0.704212   0.0   0.0   0.015  0.0248889
*98
 RCC   -0.9087555  0.0  0.704212   0.0   0.0   0.015  0.0248889
*99
 RCC   0.0 -0.9087555   0.704212   0.0   0.0   0.015  0.0248889
*100
 RCC  0.0  0.0  0.719212   0.0  0.0  0.025  0.28622
*101
 RCC  0.0  0.0  0.719212   0.0  0.0  0.025  0.34844
*102
 RCC  0.0  0.0  0.719212   0.0  0.0  0.025  0.73422
*103
 RCC  0.0  0.0  0.719212  0.0  0.0  0.199111  0.8
*104
 RCC  0.0  0.0  0.719212  0.0  0.0  0.199111  1.027288
*105
 RCC   0.9087555  0.0  0.719212   0.0   0.0   0.19111  0.0248889
*106
 RCC   0.0 0.9087555   0.719212   0.0   0.0   0.19111  0.0248889
*107
 RCC   -0.9087555  0.0  0.719212   0.0   0.0   0.19111  0.0248889
*108
 RCC   0.0 -0.9087555   0.719212   0.0   0.0   0.19111  0.0248889
*109
 RCC  0.0  0.0  0.744212   0.0  0.0  0.043445  0.28622
*110
 RCC  0.0  0.0  0.744212   0.0  0.0  0.043445  0.34844
*111
 RCC  0.0  0.0  0.744212   0.0  0.0  0.043445  0.73422
*112
```

```
  RCC  0.0  0.0  0.787657   0.0  0.0  0.068444  0.28622
*113
  RCC  0.0  0.0  0.787657   0.0  0.0  0.068444  0.73422
*114
  TRC  0.0  0.0  0.856101  0.0  0.0  0.062222  0.28622  0.34844
*115
  RCC  0.0  0.0  0.856101  0.0  0.0  0.062222  0.73422
*116
  RCC  0.0  0.0  0.918323  0.0  0.0  0.05080  0.423111
*117
  RCC  0.0  0.0  0.918323  0.0  0.0  0.05080  1.001777
*118
  RCC  0.0  0.0  0.918323  0.0  0.0  0.05080  1.027288
*119
  RCC   0.9087555  0.0  0.918323    0.0   0.0   0.05080  0.0248889
*120
  RCC   0.0 0.9087555   0.918323    0.0   0.0   0.05080  0.0248889
*121
  RCC   -0.9087555  0.0  0.918323   0.0   0.0   0.05080  0.0248889
*122
  RCC   0.0 -0.9087555   0.918323   0.0   0.0   0.05080  0.0248889
*123
  TRC  0.0  0.0  0.969123  0.0  0.0  0.0500  0.423111  0.373111
*124
  RCC  0.0  0.0  0.969123  0.0  0.0  0.0500  0.8
*125
  RCC  0.0  0.0  0.969123  0.0  0.0  0.0500  1.027288
*126
  RCC   0.9087555  0.0  0.969123    0.0   0.0   0.05  0.0248889
*127
  RCC   0.0 0.9087555   0.969123    0.0   0.0   0.05  0.0248889
*128
  RCC   -0.9087555  0.0  0.969123   0.0   0.0   0.05  0.0248889
*129
  RCC   0.0 -0.9087555   0.969123   0.0   0.0   0.05  0.0248889
*130
  RCC  0.0  0.0  1.019123  0.0  0.0  0.024666  0.373111
*131
  RCC  0.0  0.0  1.019123  0.0  0.0  0.024666  0.8
*132
  RCC  0.0  0.0  1.019123  0.0  0.0  0.024666  1.027288
*133
  RCC   0.9087555  0.0  1.019123    0.0   0.0   0.024666  0.0248889
*134
  RCC   0.0 0.9087555   1.019123    0.0   0.0   0.024666  0.0248889
*135
  RCC   -0.9087555  0.0  1.019123   0.0   0.0   0.024666  0.0248889
*136
  RCC   0.0 -0.9087555   1.019123   0.0   0.0   0.024666  0.0248889
*137
  RCC  0.0  0.0  1.043789  0.0  0.0  0.069688  0.373111
*138
  RCC  0.0  0.0  1.043789  0.0  0.0  0.069688  0.43533
*139
  RCC  0.0  0.0  1.043789  0.0  0.0  0.069688  .8
*140
  RCC  0.0  0.0  1.043789  0.0  0.0  0.069688  1.027288
*141
  RCC   0.9087555  0.0  1.043789    0.0   0.0   0.069688  0.0248889
*142
  RCC   0.0 0.9087555   1.043789    0.0   0.0   0.069688  0.0248889
*143
  RCC   -0.9087555  0.0  1.043789   0.0   0.0   0.069688  0.0248889
*144
  RCC   0.0 -0.9087555   1.043789   0.0   0.0   0.069688  0.0248889
*145
  RCC  0.0  0.0  1.113477  0.0  0.0  0.05  0.518942
*146
  RCC  0.0  0.0  1.113477  0.0  0.0  0.05  0.73422
*147
  RCC  0.0  0.0  1.163477  0.0  0.0  0.04  0.373111
*148
  RCC  0.0  0.0  1.163477  0.0  0.0  0.04  0.43533
*149
  RCC  0.0  0.0  1.163477  0.0  0.0  0.04  0.73422
*150
  RCC  0.0  0.0  1.203477  0.0  0.0  0.04  0.373111
*151
  RCC  0.0  0.0  1.203477  0.0  0.0  0.04  0.43533
*152
```

```
 RCC  0.0  0.0  1.203477  0.0  0.0  0.04  0.73422
*153
 RCC  0.0  0.0  1.243477  0.0  0.0  0.05  0.373111
*154
 RCC  0.0  0.0  1.243477  0.0  0.0  0.05  0.73422
*155
 TRC  0.0  0.0  1.293477  0.0  0.0  0.059297  0.373111  0.43533
*156
 RCC  0.0  0.0  1.293477  0.0  0.0  0.059297  0.73422
*157
 RCC  0.0  0.0  1.113477  0.0  0.0  0.239297  0.8
*158
 RCC  0.0  0.0  1.113477  0.0  0.0  0.239297  1.027288
*159
 RCC   0.9087555  0.0  1.113477   0.0   0.0   0.239297   0.0248889
*160
 RCC   0.0 0.9087555   1.113477   0.0   0.0   0.239297  0.0248889
*161
 RCC   -0.9087555  0.0  1.113477   0.0   0.0   0.239297  0.0248889
*162
 RCC   0.0 -0.9087555   1.113477   0.0   0.0   0.239297  0.0248889
*163
 RCC  0.0  0.0  1.352774  0.0  0.0  0.007620  0.4064
*164
 RCC  0.0  0.0  1.352774  0.0  0.0  0.007620  0.6096
*165
 RCC  0.0  0.0  1.352774  0.0  0.0  0.007620  1.001777
*166
 RCC  0.0  0.0  1.352774  0.0  0.0  0.007620  1.027288
*167
 RCC   0.9087555  0.0  1.352774   0.0   0.0   0.007620  0.0248889
*168
 RCC   0.0 0.9087555   1.352774   0.0   0.0   0.007620  0.0248889
*169
 RCC   -0.9087555  0.0  1.352774   0.0   0.0   0.007620  0.0248889
*170
 RCC   0.0 -0.9087555   1.352774   0.0   0.0   0.007620  0.0248889
*171
 RCC  0.0  0.0  1.360394  0.0  0.0  0.050796  0.4064
*172
 RCC  0.0  0.0  1.360394  0.0  0.0  0.050796  1.001777
*173
 RCC  0.0  0.0  1.360394  0.0  0.0  0.050796  1.027288
*174
 RCC   0.9087555  0.0  1.360394   0.0   0.0   0.050796   0.0248889
*175
 RCC   0.0 0.9087555   1.360394   0.0   0.0   0.050796  0.0248889
*176
 RCC   -0.9087555  0.0  1.360394   0.0   0.0   0.050796  0.0248889
*177
 RCC   0.0 -0.9087555   1.360394   0.0   0.0   0.050796  0.0248889
*178
 RCC  0.0  0.0  1.41119   0.0  0.0  0.007620  0.4064
*179
 RCC  0.0  0.0  1.41119   0.0  0.0  0.007620  0.6096
*180
 RCC  0.0  0.0  1.41119   0.0  0.0  0.007620  1.001777
*181
 RCC  0.0  0.0  1.41119   0.0  0.0  0.007620  1.027288
*182
 RCC   0.9087555  0.0  1.41119   0.0   0.0   0.007620  0.0248889
*183
 RCC   0.0 0.9087555   1.41119   0.0   0.0   0.007620  0.0248889
*184
 RCC   -0.9087555  0.0  1.41119   0.0   0.0   0.007620  0.0248889
*185
 RCC   0.0 -0.9087555   1.41119   0.0   0.0   0.007620  0.0248889
*186
 RCC  0.0  0.0  1.41881   0.0  0.0  0.099555  0.5080
*187
 RCC  0.0  0.0  1.41881   0.0  0.0  0.099555  1.001777
*188
 RCC  0.0  0.0  1.41881   0.0  0.0  0.099555  1.027288
*189
 RCC   0.9087555  0.0  1.418810   0.0   0.0   0.099555   0.0248889
*190
 RCC   0.0 0.9087555   1.418810   0.0   0.0   0.099555  0.0248889
*191
 RCC   -0.9087555  0.0  1.418810   0.0   0.0   0.099555  0.0248889
*192
```

```
  RCC   0.0 -0.9087555   1.418810   0.0   0.0   0.099555  0.0248889
*193
  RCC  0.0  0.0  1.518365  0.0  0.0  0.435556  0.5080
*194
  RCC  0.0  0.0  1.518365  0.0  0.0  0.435556  1.001777
*195
  RCC  0.0  0.0  1.518365  0.0  0.0  0.435556  1.027288
*196
  RCC  0.9087555  0.0  1.518365  0.0  0.0  0.435556  0.734222
*197
  RCC  0.0  0.9087555  1.518365  0.0  0.0  0.435556  0.734222
*198
  RCC  -0.9087555 0.0  1.518365  0.0  0.0  0.435556  0.734222
*199
  RCC  0.0 -0.9087555  1.518365  0.0  0.0  0.435556  0.734222
*200
  RCC  0.0  0.0  1.953921  0.0  0.0  0.018044  0.5080
*201
  RCC  0.0  0.0  1.953921  0.0  0.0  0.018044  1.001777
*202
  RCC  0.0  0.0  1.953921  0.0  0.0  0.018044  1.027288
*203
  RCC  0.0  0.0  1.971965  0.0  0.0  0.074666  1.027288
*204
  RCC  0.0  0.0  2.046631  0.0  0.0  0.248889  1.5240
*205
  RCC  0.0  0.0  0.0  0.0  0.0  2.046631  1.5240
*206  AL TOP PLATE
  RPP -2.54  7.62  -2.54  7.62  -0.2032  0.0
*207  AL BOTTOM PLATE
  RPP -2.54  7.62  -2.54  7.62  7.5565  8.1661
*208  LOW X SIDE PLATE
  RPP -2.54 -2.3368  -2.54  7.62  0.0  7.5565
*209  HIGH X SIDE PLATE
  RPP 7.4168  7.62  -2.54  7.62  0.0  7.5565
*210  LOW Y SIDE PLATE
  RPP -2.3368  7.4168 -2.54  -2.3368  0.0 7.5565
*211  HIGH Y SIDE PLATE
  RPP -2.3368  7.4168 7.4168  7.62   0.0 7.5565
*212  HOLE IN CASE TOP FOR APERTURE
  RCC  0. 0. -0.2032  0. 0. 0.2032  0.5334
*213-218  MICARTA BOARDS (6)
  RPP -2.3368  7.4168  -2.3368  7.4168  2.295525  2.454275
  RPP -2.3368  7.4168  -2.3368  7.4168  3.137535  3.296285
  RPP -2.3368  7.4168  -2.3368  7.4168  3.979545  4.138295
  RPP -2.3368  7.4168  -2.3368  7.4168  4.821555  4.980305
  RPP -2.3368  7.4168  -2.3368  7.4168  5.663565  5.822315
  RPP -2.3368  7.4168  -2.3368  7.4168  6.505575  6.64325
*219-224  VOIDS BETWEEN MICARTA BOARDS
  RPP -2.3368  7.4168  -2.3368  7.4168  2.454275 3.137535
  RPP -2.3368  7.4168  -2.3368  7.4168  3.296285 3.979545
  RPP -2.3368  7.4168  -2.3368  7.4168  4.138295 4.821555
  RPP -2.3368  7.4168  -2.3368  7.4168  4.980305 5.663565
  RPP -2.3368  7.4168  -2.3368  7.4168  5.822315 6.505575
  RPP -2.3368  7.4168  -2.3368  7.4168  6.64325  7.5565
*225-228  STAINLESS CORNER BOLTS (4)
  RCC -1.79605  -1.79605  -0.2032  0.0  0.0  8.3693  0.1058333
  RCC  5.82395  -1.79605  -0.2032  0.0  0.0  8.3693  0.1058333
  RCC  5.82395   5.82395  -0.2032  0.0  0.0  8.3693  0.1058333
  RCC -1.79605   5.82395  -0.2032  0.0  0.0  8.3693  0.1058333
*229-234  PMMA SPACERS WRAPPED AROUND CORNER BOLT#1
  RCC -1.79605  -1.79605  2.454275  0.0  0.0  0.68326  0.21167
  RCC -1.79605  -1.79605  3.296285  0.0  0.0  0.68326  0.21167
  RCC -1.79605  -1.79605  4.138295  0.0  0.0  0.68326  0.21167
  RCC -1.79605  -1.79605  4.980305  0.0  0.0  0.68326  0.21167
  RCC -1.79605  -1.79605  5.822315  0.0  0.0  0.68326  0.21167
  RCC -1.79605  -1.79605  6.664325  0.0  0.0  0.892175  0.21167
*235-240  PMMA SPACERS WRAPPED AROUND CORNER BOLT#2
  RCC 5.82395   -1.79605  2.454275  0.0  0.0  0.68326  0.21167
  RCC 5.82395   -1.79605  3.296285  0.0  0.0  0.68326  0.21167
  RCC 5.82395   -1.79605  4.138295  0.0  0.0  0.68326  0.21167
  RCC 5.82395   -1.79605  4.980305  0.0  0.0  0.68326  0.21167
  RCC 5.82395   -1.79605  5.822315  0.0  0.0  0.68326  0.21167
```

```
  RCC 5.82395    -1.79605  6.664325  0.0  0.0  0.892175  0.21167
*241-246  PMMA SPACERS WRAPPED AROUND CORNER BOLT#3
  RCC 5.82395    5.82395   2.454275  0.0  0.0  0.68326  0.21167
  RCC 5.82395    5.82395   3.296285  0.0  0.0  0.68326  0.21167
  RCC 5.82395    5.82395   4.138295  0.0  0.0  0.68326  0.21167
  RCC 5.82395    5.82395   4.980305  0.0  0.0  0.68326  0.21167
  RCC 5.82395    5.82395   5.822315  0.0  0.0  0.68326  0.21167
  RCC 5.82395    5.82395   6.664325  0.0  0.0  0.892175  0.21167
*247-252  PMMA SPACERS WRAPPED AROUND CORNER BOLT#4
  RCC -1.79605  5.82395   2.454275  0.0  0.0  0.68326  0.21167
  RCC -1.79605  5.82395   3.296285  0.0  0.0  0.68326  0.21167
  RCC -1.79605  5.82395   4.138295  0.0  0.0  0.68326  0.21167
  RCC -1.79605  5.82395   4.980305  0.0  0.0  0.68326  0.21167
  RCC -1.79605  5.82395   5.822315  0.0  0.0  0.68326  0.21167
  RCC -1.79605  5.82395   6.664325  0.0  0.0  0.892175  0.21167
*253 VOID REGION BETWEEN TOP PLATE AND FIRST MICARTA BOARD
  RPP   -2.3368 7.4168 -2.3368 7.4168 0.0 2.295525
*254  EXTERIOR VOID ABOVE TOP Z PLATE
  RPP  -3.54  8.62  -3.54  8.62  -2.2032  -0.2032
*255  EXTERIOR VOID BELOW BOTTOM Z PLATE
  RPP  -3.54  8.62  -3.54  8.62  8.1661  10.1661
*256  EXTERIOR VOID OUTSIDE LOWER X PLATE
  RPP  -3.54  -2.54  -3.54  8.62  0.0  7.5565
*257  EXTERIOR VOID OUTSIDE UPPER X PLATE
  RPP  7.62  8.62    -3.54  8.62  0.0  7.5565
*258  EXTERIOR VOID OUTSIDE LOWER Y PLATE
  RPP  -2.54  7.62  -3.54  -2.54  0.0  7.5565
*259  EXTERIOR VOID OUTSIDE UPPER Y PLATE
  RPP  -2.54  7.62  7.62  8.62    0.0  7.5565
*260
  SPH  0.0  0.0  1.2  30.0
  END
*VOID
  Z01 +1
  Z02 +2
  Z03 +3
  Z04 +4
  Z05 +5
  Z06 +6
  Z07 +7
  Z08 +8
  Z09 +9
  Z10 +10
  Z11 +11
  Z12 +12
  Z13 +13
  Z14 +14
  Z15 +15
  Z16 +16
  Z17 +17
  Z18 +18
*COPPER
  Z19 +19 -1
  Z20 +20 -2
  Z21 +21 -3
  Z22 +22 -4
  Z23 +23 -5
  Z24 +24 -6
  Z25 +25 -7
  Z26 +26 -8
  Z27 +27 -9
  Z28 +28 -10
  Z29 +29 -11
  Z30 +30 -12
  Z31 +31 -13
  Z32 +32 -14
  Z33 +33 -15
  Z34 +34 -16
  Z35 +35 -17
  Z36 +36 -18
  Z37 +37 -39
  Z38 +38 -40
*AL FOIL
  Z39 +39
*TUNGSTEN DISK
  Z40 +40 -41
*VOID APERTURE
  Z41 +41
*COPPER
  Z42 +42 -19 -20 -21 -22 -23 -24 -25 -26 -27 -28 -29 -30 -31 -32
```

```
*VOID
  Z43 +43 -33 -34 -35 -36 -37 -38 -44 -45 -46 -47
*PMMA RODS
  Z44 +44
  Z45 +45
  Z46 +46
  Z47 +47
*STAINLESS BOLTS
  Z48 +48
  Z49 +49
  Z50 +50
  Z51 +51
  Z52 +52
  Z53 +53
  Z54 +54
  Z55 +55
*VOID
  Z56 +56
*GOLD
  Z57 +57 -56
*VOID
  Z58 +58 -56 -57 -59 -60 -61 -62
*PMMA RODS
  Z59 +59
  Z60 +60
  Z61 +61
  Z62 +62
*VOID
  Z63 +63
*PCB ANNULUS
  Z64 +68 -63 -64 -65 -66 -67
*PMMA RODS
  Z65 +64
  Z66 +65
  Z67 +66
  Z68 +67
*VOID
  Z69 +69 -63 -64 -65 -66 -67 -68
  Z70 +70
*BRASS ANNULUS
  Z71 +71 -70
*VOID
  Z72 +72 -70 -71 -73 -74 -75 -76
*PMMA RODS
  Z73 +73
  Z74 +74
  Z75 +75
  Z76 +76
*VOID
  Z77 +77
*BRASS ANNULUS
  Z78 +78 -77
*VOID
  Z79 +79 -77 -78 -80 -81 -82 -83
*PMMA RODS
  Z80 +80
  Z81 +81
  Z82 +82
  Z83 +83
*VOID
  Z84 +84
*RUBBER ANNULUS
  Z85 +85 -84
*PMMA SPACER ANNULUS
  Z86 +86 -84 -85
*VOID ANNULUS
  Z87 +87 -84 -85 -86 -88 -89 -90 -91
*PMMA RODS
  Z88 +88
  Z89 +89
  Z90 +90
  Z91 +91
*DFT ELECTRICALLY ACTIVE PART
  Z92 +92
*DFT ELECTRICALLY INACTIVE PART
  Z93 +93 -92
*PMMA
  Z94 +94 -92 -93
*VOID
  Z95 +95 -92 -93 -94 -96 -97 -98 -99
```

```
*PMMA RODS
  Z96 +96
  Z97 +97
  Z98 +98
  Z99 +99
*VOID
  Z100 +100
*RUBBER ANNULUS
  Z101 +101 -100
*VOID
  Z102 +102 -100 -101
  Z103 +109
*RUBBER ANNULUS
  Z104 +110 -109
*BRASS
  Z105 +111 -109 -110
*VOID
  Z106 +112
*BRASS
  Z107 +113 -112
*VOID
  Z108 +114
*BRASS
  Z109 +115 -114
*PMMA
  Z110 +103 -100 -101 -102 -109 -110 -111 -112 -113 -114 -115
*VOID
  Z111 +104 -102 -103 -105 -106 -107 -108 -109 -110
        -111 -112 -113 -114 -115
*PMMA RODS
  Z112 +105
  Z113 +106
  Z114 +107
  Z115 +108
*VOID
  Z116 +116
*PCB ANNULUS
  Z117 +117 -116 -119 -120 -121 -122
*VOID
  Z118 +118 -116 -117 -119 -120 -121 -122
*PMMA RODS
  Z119 +119
  Z120 +120
  Z121 +121
  Z122 +122
*VOID
  Z123 +123
*BRASS ANNULUS
  Z124 +124 -123
*VOID ANNULUS
  Z125 +125 -123 -124 -126 -127 -128 -129
*PMMA RODS
  Z126 +126
  Z127 +127
  Z128 +128
  Z129 +129
*VOID
  Z130 +130
*BRASS ANNULUS
  Z131 +131 -130
*VOID ANNULUS
  Z132 +132 -130 -131 -133 -134 -135 -136
*PMMA RODS
  Z133 +133
  Z134 +134
  Z135 +135
  Z136 +136
*VOID
  Z137 +137
*RUBBER ANNULUS
  Z138 +138 -137
*PMMA
  Z139 +139 -137 -138
*VOID
  Z140 +140 -137 -138 -139 -141 -142 -143 -144
*PMMA RODS
  Z141 +141
  Z142 +142
  Z143 +143
  Z144 +144
```

```
*DBT ELLECTRICALLY ACTIVE PART
  Z145 +145
*DBT ELECTRICALLY INACTIVE PART
  Z146 +146 -145
*VOID
  Z147 +147
*RUBBER ANNULUS
  Z148 +148 -147
*VOID
  Z149 +149 -147 -148
  Z150 +150
*RUBBER ANNULUS
  Z151 +151 -150
*BRASS ANNULUS
  Z152 +152 -150 -151
*VOID
  Z153 +153
*BRASS ANNULUS
  Z154 +154 -153
*VOID
  Z155 +155
*BRASS ANNULUS
  Z156 +156 -155
*PMMA SPACER
  Z157 +157 -145 -146 -147 -148 -149 -150 -151 -152 -153 -154 -155 -156
*VOID
  Z158 +158 -145 -146 -147 -148 -149 -150 -151 -152 -153 -154 -155 -156
       -157 -159 -160 -161 -162
*PMMA RODS
  Z159 +159
  Z160 +160
  Z161 +161
  Z162 +162
*VOID
  Z163 +163
*GOLD
  Z164 +164  -163
*VOID
  Z165 +165 -163 -164 -167 -168 -169 -170
  Z166 +166 -163 -164 -165 -167 -168 -169 -170
*PMMA RODS
  Z167 +167
  Z168 +168
  Z169 +169
  Z170 +170
*VOID
  Z171 +171
*PCB
  Z172 +172 -171 -174 -175 -176 -177
*VOID
  Z173 +173 -171 -172
*PMMA RODS
  Z174 +174
  Z175 +175
  Z176 +176
  Z177 +177
*VOID
  Z178 +178
*GOLD SPACER
  Z179 +179 -178
*VOID
  Z180 +180 -178 -179 -182 -183 -184 -185
*VOID
  Z181 +181 -178 -179 -180 -182 -183 -184 -185
*PMMA RODS
  Z182 +182
  Z183 +183
  Z184 +184
  Z185 +185
*VOID
  Z186 +186
*PMMA
  Z187 +187 -186 -189 -190 -191 -192
*VOID
  Z188 +188 -186 -187 -189 -190 -191 -192
*PMMA RODS
  Z189 +189
  Z190 +190
  Z191 +191
  Z192 +192
```

```
*VOID
  Z193 +193
*PMMA
  Z194 +194 -193 -196 -197 -198 -199
*VOID
  Z195 +195 -193 -194 -196 -197 -198 -199
*PMMA RODS
  Z196 +196
  Z197 +197
  Z198 +198
  Z199 +199
*VOID
  Z200 +200
*PMMA
  Z201 +201 -200
*VOID
  Z202 +202 -200 -201
  Z203 +203
*COPPER
  Z204 +204
  Z205 +205
       -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12 -13 -14 -15
      -16 -17 -18 -19 -20 -21 -22 -23 -24 -25 -26 -27 -28
      -29 -30 -31 -32 -33 -34 -35 -36 -37 -38 -39 -40 -41
      -42 -43 -44 -45 -46 -47 -48 -49 -50 -51 -52 -53 -54
      -55 -56 -57 -58 -59 -60 -61 -62 -63 -64 -65 -66 -67
      -68 -69 -70 -71 -72 -73 -74 -75 -76 -77 -78 -79 -80
      -81 -82 -83 -84 -85 -86 -87 -88 -89 -90 -91 -92 -93
      -94 -95 -96 -97 -98 -99 -100 -101 -102 -103 -104 -105
      -106 -107 -108 -109 -110 -111 -112 -113 -114 -115
      -116 -117 -118 -119 -120 -121 -122 -123 -124 -125
      -126 -127 -128 -129 -130 -131 -132 -133 -134 -135
      -136 -137 -138 -139 -140 -141 -142 -143 -144 -145
      -146 -147 -148 -149 -150 -151 -152 -153 -154 -155
      -156 -157 -158 -159 -160 -161 -162 -163 -164 -165
      -166 -167 -168 -169 -170 -171 -172 -173 -174 -175
      -176 -177 -178 -179 -180 -181 -182 -183 -184 -185
      -186 -187 -188 -189 -190 -191 -192 -193 -194 -195
      -196 -197 -198 -199 -200 -201 -202 -203
*TOP PLATE WITH HOLE FOR INSTRUMENT AND 4 BOLT HOLES
  Z206 +206 -212 -225 -226 -227 -228
*BOTTOM PLATE
  Z207 +207
*X-PLATES
  Z208 +208
  Z209 +209
*Y-PLATES
  Z210 +210
  Z211 +211
*VOID REGION BETWEEN TOP PLATE AND FIRST MICARTA BOARD
*(EXCLUDES THE CEASE TELESCOPE, CORNER BOLTS)
  Z212 +253 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12 -13 -14 -15
      -16 -17 -18 -19 -20 -21 -22 -23 -24 -25 -26 -27 -28
      -29 -30 -31 -32 -33 -34 -35 -36 -37 -38 -39 -40 -41
      -42 -43 -44 -45 -46 -47 -48 -49 -50 -51 -52 -53 -54
      -55 -56 -57 -58 -59 -60 -61 -62 -63 -64 -65 -66 -67
      -68 -69 -70 -71 -72 -73 -74 -75 -76 -77 -78 -79 -80
      -81 -82 -83 -84 -85 -86 -87 -88 -89 -90 -91 -92 -93
      -94 -95 -96 -97 -98 -99 -100 -101 -102 -103 -104 -105
      -106 -107 -108 -109 -110 -111 -112 -113 -114 -115
      -116 -117 -118 -119 -120 -121 -122 -123 -124 -125
      -126 -127 -128 -129 -130 -131 -132 -133 -134 -135
      -136 -137 -138 -139 -140 -141 -142 -143 -144 -145
      -146 -147 -148 -149 -150 -151 -152 -153 -154 -155
      -156 -157 -158 -159 -160 -161 -162 -163 -164 -165
      -166 -167 -168 -169 -170 -171 -172 -173 -174 -175
      -176 -177 -178 -179 -180 -181 -182 -183 -184 -185
      -186 -187 -188 -189 -190 -191 -192 -193 -194 -195
      -196 -197 -198 -199 -200 -201 -202 -203 -204 -205
      -225 -226 -227 -228
*MICARTA BOARDS (6) EXCLUDES BOLTS
 Z213 +213 -225 -226 -227 -228
 Z214 +214 -225 -226 -227 -228
 Z215 +215 -225 -226 -227 -228
 Z216 +216 -225 -226 -227 -228
 Z217 +217 -225 -226 -227 -228
 Z218 +218 -225 -226 -227 -228
*VOIDS BETWEEN MICARTA BOARDS (6) (EXCLUDES BOLTS AND PMMA SPACERS)
 Z219 +219 -229 -225 -235 -226 -241 -227 -247 -228
 Z220 +220 -230 -225 -236 -226 -242 -227 -248 -228
```

```
 Z221 +221 -231 -225 -237 -226 -243 -227 -249 -228
 Z222 +222 -232 -225 -238 -226 -244 -227 -250 -228
 Z223 +223 -233 -225 -239 -226 -245 -227 -251 -228
 Z224 +224 -234 -225 -240 -226 -246 -227 -252 -228
*VOID REGION ABOVE TOP Z-PLATE
 Z225 +254
*VOID REGION BELOW BOTTOM Z-PLATE
 Z226 +255
*VOID REGION OUTSIDE LOWER X-PLATE
 Z227 +256
*VOID REGION OUTSIDE UPPER X-PLATE
 Z228 +257
*VOID REGION OUTSIDE LOWER Y-PLATE
 Z229 +258
*VOID REGION OUTSIDE UPPER Y-PLATE
 Z230 +259
*VOID CYLINDRICAL REGION ABOVE INSTRUMENT APERTURE
 Z231 +212
*CORNER BOLT 1
 Z232 +225
*CORNER BOLT 2
 Z233 +226
*CORNER BOLT 3
 Z234 +227
*CORNER BOLT 4
 Z235 +228
*PMMA SPACERS AROUND CORNER BOLT 1
 Z236 +229 -225
 Z237 +230 -225
 Z238 +231 -225
 Z239 +232 -225
 Z240 +233 -225
 Z241 +234 -225
*PMMA SPACERS AROUND CORNER BOLT 2
 Z242 +235 -226
 Z243 +236 -226
 Z244 +237 -226
 Z245 +238 -226
 Z246 +239 -226
 Z247 +240 -226
*PMMA SPACERS AROUND CORNER BOLT 3
 Z248 +241 -227
 Z249 +242 -227
 Z250 +243 -227
 Z251 +244 -227
 Z252 +245 -227
 Z253 +246 -227
*PMMA SPACERS AROUND CORNER BOLT 4
 Z254 +247 -228
 Z255 +248 -228
 Z256 +249 -228
 Z257 +250 -228
 Z258 +251 -228
 Z259 +252 -228
*ESCAPE
 Z260 +260
        -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12 -13 -14 -15
       -16 -17 -18 -19 -20 -21 -22 -23 -24 -25 -26 -27 -28
       -29 -30 -31 -32 -33 -34 -35 -36 -37 -38 -39 -40 -41
       -42 -43 -44 -45 -46 -47 -48 -49 -50 -51 -52 -53 -54
       -55 -56 -57 -58 -59 -60 -61 -62 -63 -64 -65 -66 -67
       -68 -69 -70 -71 -72 -73 -74 -75 -76 -77 -78 -79 -80
       -81 -82 -83 -84 -85 -86 -87 -88 -89 -90 -91 -92 -93
       -94 -95 -96 -97 -98 -99 -100 -101 -102 -103 -104 -105
       -106 -107 -108 -109 -110 -111 -112 -113 -114 -115
       -116 -117 -118 -119 -120 -121 -122 -123 -124 -125
       -126 -127 -128 -129 -130 -131 -132 -133 -134 -135
       -136 -137 -138 -139 -140 -141 -142 -143 -144 -145
       -146 -147 -148 -149 -150 -151 -152 -153 -154 -155
       -156 -157 -158 -159 -160 -161 -162 -163 -164 -165
       -166 -167 -168 -169 -170 -171 -172 -173 -174 -175
       -176 -177 -178 -179 -180 -181 -182 -183 -184 -185
       -186 -187 -188 -189 -190 -191 -192 -193 -194 -195
       -196 -197 -198 -199 -200 -201 -202 -203 -204 -205
       -206 -207 -208 -209 -210 -211 -212 -213 -214 -215
       -216 -217 -218 -219 -220 -221 -222 -223 -224 -225
       -226 -227 -228 -229 -230 -231 -232 -233 -234 -235
       -236 -237 -238 -239 -240 -241 -242 -243 -244 -245
       -246 -247 -248 -249 -250 -251 -252 -253 -254 -255
       -256 -257 -258 -259
```

```
END
 0.022703333 0.020592595 0.018584814 0.016679998 0.014878148
 0.013179258 0.011583334 0.010090370 0.008700370 0.007413333
 0.006229259 0.005148149 0.004170000 0.003294815 0.002522592
 0.001853333 0.001287037 0.000823704 0.022267310 0.024378050
 0.026385830 0.028290650 0.030092500 0.031791390 0.033387310
 0.034880270 0.036270270 0.037557310 0.038741380 0.039822490
 0.040800640 0.041675830 0.042448050 0.043117310 0.043683610
 0.044146940 0.001096824 0.060812810 0.000496624 0.027453117
 0.000081922 0.641797483 0.454472780 0.000116487 0.000116487
 0.000116487 0.000116487 0.073521651 0.073521651 0.073521651
 0.073521651 0.009608479 0.009608479 0.009608479 0.009608479
 0.002590535 0.002110838 0.023479404 0.000016581 0.000016581
 0.000016581 0.000016581 0.015445910 0.144319251 0.000098861
 0.000098861 0.000098861 0.000098861 0.008261055 0.007567282
 0.042473011 0.032279331 0.000048434 0.000048434 0.000048434
 0.000048434 0.012812156 0.087280497 0.064566441 0.000096880
 0.000096880 0.000096880 0.000096880 0.016013781 0.007719066
 0.101371907 0.080700926 0.000121089 0.000121089 0.000121089
 0.000121089 0.007619198 0.017784303 0.004755789 0.019454755
 0.000029191 0.000029191 0.000029191 0.000029191 0.006434131
 0.003101422 0.032803617 0.011181233 0.005389650 0.057006128
 0.017615106 0.098299384 0.016013781 0.089363337 0.063128665
 0.258305967 0.000371916 0.000371916 0.000371916 0.000371916
 0.028570788 0.131194383 0.008261055 0.000098861 0.000098861
 0.000098861 0.000098861 0.028120855 0.072410122 0.064849176
 0.000097304 0.000097304 0.000097304 0.000097304 0.010787598
 0.038806342 0.031991400 0.000048002 0.000048002 0.000048002
 0.000048002 0.030477827 0.011012329 0.098625898 0.090384185
 0.000135619 0.000135619 0.000135619 0.000135619 0.042301673
 0.042376671 0.017493874 0.006320933 0.043927863 0.017493874
 0.006320933 0.043927863 0.021867344 0.062811002 0.025933357
 0.074490078 0.075869732 0.310364306 0.000465692 0.000465692
 0.000465692 0.000465692 0.003953778 0.004942222 0.015128090
 0.001239162 0.000014829 0.000014829 0.000014829 0.000014829
 0.026356442 0.133396149 0.008260399 0.000098853 0.000098853
 0.000098853 0.000098853 0.003953778 0.004942222 0.015128090
 0.001239162 0.000014829 0.000014829 0.000014829 0.000014829
 0.080712430 0.232580170 0.016189575 0.000193742 0.000193742
 0.000193742 0.000197432 0.353119195 1.013637780 0.070829749
 0.007376472 0.007376472 0.007376472 0.007376472 0.014628849
 0.042259701 0.002934299 0.247546718 1.816040640 10.59448620
 20.97544    62.92632    15.60048    15.60048    14.97646
 14.97646    201.3069    15.07997    15.07997    15.07997
 15.07997    15.07997    13.07801    64.61568    64.61568
 64.61568    64.61568    64.61568    86.37763    147.8656
 147.8656    91.88704    91.88704    76.77404    76.77404
 0.1816266   0.2944989   0.2944989   0.2944989   0.2944989
 0.07213074 0.07213074  0.07213074  0.07213074  0.07213074
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Actual input data must be arranged in a single column. Four columns are used here to conserve space.

```
*********************** SOURCE ********************
ELECTRONS
ENERGY 9.9
POSITION 0.0 0.0 -0.25
  RADIUS 1.4
* DEFAULT DIRECTION
     DIRECTION 0.0  0.0
**********************  OPTIONS  *******************
HISTORIES 25000
```

APPENDIX 6

ITS-XGEN Input File to Generate Electron and Photon Cross Section Tables for CEASE Telescope

(For chemical compounds, material density [g/cm^3] must be specified, and material compositions are defined by specifying elemental weight fractions.)

```
TITLE
  CEASE  10 MEV TEST PROBLEM (10 MATL'S)
ENERGY 12.0
*BRASS
MATERIAL CU   0.7         NI  0.3
  DENSITY  8.53
*ALUMINUM
MATERIAL AL
*TUNGSTEN ALLOY
MATERIAL  W  0.95  NI  0.035  CU  0.015
  DENSITY 18.0
*GOLD
MATERIAL  AU
*MICARTA FR-4
MATERIAL  O 0.4691566  SI 0.2573466  CA .1478866  AL 0.06351008
                      B  0.01552755  MA  0.01483714  FE 0.01279773
                      TI  0.003597  MG  0.030152
 DENSITY 2.54
*STAINLESS
MATERIAL  FE 0.71  MN  0.065  SI  0.01  CU  0.17  NI  0.045
 DENSITY 8.0
* CONDUCTIVE SILICONE ELASTOMER
MATERIAL SI 0.0947  O  0.0539  C 0.0810  H  0.0204  NI 0.3770  AG 0.3730
 DENSITY  7.4723
*PMMA
MATERIAL  H  0.080538  C  0.599848  O  0.319614
 DENSITY  1.190
*SILICON
MATERIAL SI
*COPPER ALLOY 145
MATERIAL CU  0.995  TE  0.005
 DENSITY 8.92
```

APPENDIX 7

ACCEPT Output Listing of Energy and Charge Deposition in CEASE Telescope, Frame and Case resulting from 9.9 MeV Electron Beam Normally Incident on Case Top Directly above Telescope ("SZONE" numbers correspond to the cell labels shown in Figure 13)

ENERGY AND CHARGE DEPOSITION
(NORMALIZED TO ONE SOURCE PARTICLE)

		ENERGY(MEV)				CHARGE(ELECTRONS)			
SZONE	MAT.	PRIM	KNOCK	G-SEC	TOTAL	PRIM	KNOCK	G-SEC	TOTAL
1	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
2	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
3	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
4	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
5	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
6	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
7	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
8	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
9	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
10	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
11	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
12	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
13	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
14	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
15	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
16	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
17	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
18	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
19	10	5.312E-02 2	1.761E-04 99	7.516E-04 13	5.405E-02 2	1.360E-03 17	5.200E-04 99	-1.200E-04 99	1.760E-03 50
20	10	6.493E-02 2	7.804E-05 99	1.032E-03 12	6.604E-02 3	2.000E-03 13	5.200E-04 99	8.000E-05 99	2.600E-03 27
21	10	7.762E-02 2	-1.617E-03 43	1.235E-03 8	7.724E-02 1	3.680E-03 9	-1.280E-03 42	0.000E+00 99	2.400E-03 23
22	10	8.712E-02 2	2.225E-04 99	1.578E-03 11	8.892E-02 2	4.800E-03 10	-4.000E-05 99	8.000E-05 99	4.840E-03 17
23	10	9.619E-02 2	2.784E-04 99	2.033E-03 12	9.851E-02 2	5.320E-03 3	2.000E-04 99	-1.200E-04 99	5.400E-03 15
24	10	1.071E-01 2	-2.224E-04 99	2.047E-03 7	1.089E-01 2	8.280E-03 8	1.600E-04 99	-2.800E-04 98	8.160E-03 14
25	10	1.126E-01 2	-2.016E-03 28	2.321E-03 6	1.129E-01 1	9.560E-03 7	-1.440E-03 43	-4.000E-05 99	8.080E-03 9
26	10	1.162E-01 1	4.533E-04 99	2.241E-03 9	1.189E-01 2	1.032E-02 6	2.000E-04 99	-8.000E-05 99	1.044E-02 9
27	10	1.168E-01 2	-2.122E-04 99	2.617E-03 10	1.192E-01 2	1.236E-02 3	-6.000E-04 99	-3.600E-04 54	1.140E-02 9
28	10	1.173E-01 3	8.089E-04 82	3.152E-03 8	1.213E-01 2	1.144E-02 7	1.000E-03 78	3.600E-04 90	1.280E-02 9
29	10	1.172E-01 1	-3.888E-04 99	2.994E-03 8	1.198E-01 2	1.340E-02 3	-2.400E-04 99	-2.000E-04 99	1.296E-02 6
30	10	1.143E-01 2	7.389E-04 76	3.410E-03 8	1.185E-01 2	1.464E-02 5	9.600E-04 72	-2.400E-04 99	1.536E-02 7
31	10	1.071E-01 2	-4.644E-04 99	3.739E-03 8	1.104E-01 2	1.352E-02 4	-8.000E-04 45	3.600E-04 99	1.308E-02 5
32	10	1.006E-01 2	4.166E-04 99	3.501E-03 6	1.045E-01 2	1.424E-02 3	4.000E-04 99	-5.200E-04 57	1.412E-02 2
33	10	9.533E-02 3	4.171E-04 99	3.377E-03 6	9.912E-02 2	1.336E-02 6	8.000E-04 78	-3.659E-20 99	1.416E-02 6
34	10	9.120E-02 3	-3.282E-04 99	3.307E-03 7	9.418E-02 3	1.348E-02 8	2.800E-04 99	-4.000E-05 99	1.372E-02 9
35	10	8.563E-02 3	-8.710E-04 79	3.207E-03 8	8.796E-02 4	1.412E-02 5	-2.800E-04 99	-2.400E-04 99	1.360E-02 7
36	10	8.042E-02 3	9.181E-04 41	3.995E-03 7	8.533E-02 2	1.332E-02 6	-1.200E-04 99	2.400E-04 99	1.344E-02 7
37	10	1.243E-03 7	-5.473E-05 98	1.202E-04 19	1.309E-03 8	4.000E-05 99	-4.000E-05 99	-1.600E-04 67	-1.600E-04 85

38	10	5.799E-02	4	3.063E-04	99	4.499E-03	6	6.280E-02	4	1.492E-02	6	2.800E-04	99	8.000E-05	99	1.528E-02	7
39	2	5.912E-04	3	3.721E-05	77	1.944E-05	34	6.479E-04	5	0.000E+00	99	4.000E-05	99	1.600E-04	55	2.000E-04	54
40	3	1.387E-01	2	5.829E-05	99	1.328E-02	3	1.520E-01	2	1.692E-02	5	8.000E-05	99	-6.000E-04	32	1.640E-02	5
41	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
42	10	1.886E+00	1	5.569E-03	35	4.490E-02	3	1.936E+00	1	1.868E-01	1	4.720E-03	19	-1.320E-03	29	1.902E-01	1
43	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
44	8	3.014E-05	52	4.509E-07	99	0.000E+00	99	3.059E-05	52	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
45	8	2.678E-05	41	1.215E-06	99	0.000E+00	99	2.800E-05	39	4.000E-05	99	0.000E+00	99	0.000E+00	99	4.000E-05	99
46	8	2.487E-05	37	0.000E+00	99	0.000E+00	99	2.487E-05	37	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
47	8	3.477E-05	34	0.000E+00	99	0.000E+00	99	3.477E-05	34	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
48	6	5.783E-02	5	6.235E-04	38	2.218E-03	16	6.067E-02	5	6.360E-03	7	5.200E-04	56	8.000E-05	99	6.960E-03	9
49	6	5.685E-02	7	2.579E-04	99	3.138E-03	13	6.024E-02	8	6.680E-03	6	1.600E-04	99	-1.600E-04	93	6.680E-03	9
50	6	6.700E-02	3	-2.625E-04	92	2.824E-03	15	6.956E-02	3	7.200E-03	7	-3.200E-04	95	-3.200E-04	45	6.560E-03	9

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ENERGY AND CHARGE DEPOSITION
(NORMALIZED TO ONE SOURCE PARTICLE)

		ENERGY(MEV)								CHARGE(ELECTRONS)							
SZONE	MAT.	PRIM		KNOCK		G-SEC		TOTAL		PRIM		KNOCK		G-SEC		TOTAL	
51	6	5.999E-02	5	1.126E-04	99	1.900E-03	8	6.200E-02	5	6.840E-03	6	4.000E-05	99	-2.400E-04	67	6.640E-03	6
52	6	0.000E+00	99	0.000E+00	99	2.325E-05	67	2.325E-05	67	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
53	6	4.963E-05	99	0.000E+00	99	1.142E-04	63	1.638E-04	57	4.000E-05	99	0.000E+00	99	4.000E-05	99	8.000E-05	67
54	6	0.000E+00	99	0.000E+00	99	5.871E-05	54	5.871E-05	54	0.000E+00	99	0.000E+00	99	-4.000E-05	99	-4.000E-05	99
55	6	3.170E-05	99	0.000E+00	99	1.227E-04	74	1.545E-04	60	4.000E-05	99	0.000E+00	99	0.000E+00	99	4.000E-05	99
56	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
57	4	4.387E-03	7	3.388E-05	99	9.371E-04	13	5.358E-03	8	1.240E-03	21	2.400E-04	57	8.000E-05	99	1.560E-03	21
58	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
59	8	1.684E-06	99	0.000E+00	99	0.000E+00	99	1.684E-06	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
60	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
61	8	5.352E-06	57	0.000E+00	99	0.000E+00	99	5.352E-06	57	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
62	8	1.668E-06	69	-2.327E-05	99	0.000E+00	99	-2.160E-05	99	0.000E+00	99	-4.000E-05	99	0.000E+00	99	-4.000E-05	99
63	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
64	5	4.497E-02	3	7.062E-05	99	1.979E-03	10	4.702E-02	3	8.040E-03	7	-4.000E-04	99	-3.200E-04	99	7.320E-03	10
65	8	1.532E-05	41	0.000E+00	99	0.000E+00	99	1.532E-05	41	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
66	8	1.653E-05	45	-3.114E-05	99	0.000E+00	99	-1.462E-05	99	0.000E+00	99	-4.000E-05	99	0.000E+00	99	-4.000E-05	99
67	8	3.109E-05	40	3.966E-06	99	0.000E+00	99	3.506E-05	41	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
68	8	3.447E-05	38	1.288E-05	99	0.000E+00	99	4.735E-05	39	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
69	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
70	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
71	1	3.207E-02	3	1.074E-04	99	2.779E-03	9	3.495E-02	3	8.600E-03	4	2.400E-04	99	6.000E-04	57	9.440E-03	10
72	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
73	8	1.990E-07	99	0.000E+00	99	7.060E-06	99	7.259E-06	97	0.000E+00	99	0.000E+00	99	4.000E-05	99	4.000E-05	99
74	8	9.080E-06	69	0.000E+00	99	0.000E+00	99	9.080E-06	69	4.000E-05	99	0.000E+00	99	0.000E+00	99	4.000E-05	99
75	8	1.615E-05	58	0.000E+00	99	0.000E+00	99	1.615E-05	58	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
76	8	8.043E-06	59	6.298E-06	99	0.000E+00	99	1.434E-05	50	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
77	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
78	1	4.863E-02	3	-2.189E-04	99	4.789E-03	6	5.320E-02	3	1.196E-02	7	-2.000E-04	99	-2.800E-04	85	1.148E-02	11
79	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
80	8	8.420E-06	62	0.000E+00	99	0.000E+00	99	8.420E-06	62	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
81	8	4.955E-06	67	0.000E+00	99	0.000E+00	99	4.955E-06	67	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
82	8	1.808E-05	33	6.360E-06	99	0.000E+00	99	2.444E-05	41	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99

83	8	0.000E+00 99	0.000E+00 99	5.249E-06 99	5.249E-06 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
84	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
85	7	5.922E-03 10	5.564E-05 99	4.165E-04 16	6.394E-03 9	8.000E-04 26	1.200E-04 99	4.000E-05 99	9.600E-04 34
86	8	8.411E-03 5	2.302E-04 61	8.309E-04 14	9.472E-03 5	1.920E-03 15	2.000E-04 75	2.800E-04 74	2.400E-03 18
87	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
88	8	2.405E-05 51	0.000E+00 99	0.000E+00 99	2.405E-05 51	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
89	8	3.967E-05 53	0.000E+00 99	0.000E+00 99	3.967E-05 53	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
90	8	1.236E-05 52	0.000E+00 99	0.000E+00 99	1.236E-05 52	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
91	8	1.852E-05 45	3.849E-06 99	0.000E+00 99	2.237E-05 45	0.000E+00 99	4.000E-05 99	0.000E+00 99	4.000E-05 99
92	9	2.405E-03 3	-1.541E-05 99	2.039E-04 17	2.593E-03 3	1.600E-04 41	4.000E-05 99	1.600E-04 55	3.600E-04 39
93	9	2.302E-03 6	-5.833E-05 99	2.131E-04 7	2.457E-03 6	6.400E-04 19	-8.000E-05 99	-1.600E-04 93	4.000E-04 37
94	8	3.884E-04 13	4.983E-05 49	3.286E-05 55	4.710E-04 9	1.600E-04 55	8.000E-05 67	4.000E-05 99	2.800E-04 37
95	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
96	8	8.803E-06 44	0.000E+00 99	0.000E+00 99	8.803E-06 44	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
97	8	5.799E-06 45	0.000E+00 99	0.000E+00 99	5.799E-06 45	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
98	8	6.620E-06 57	0.000E+00 99	0.000E+00 99	6.620E-06 57	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
99	8	4.768E-06 99	0.000E+00 99	0.000E+00 99	4.768E-06 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
100	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99

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ENERGY AND CHARGE DEPOSITION
(NORMALIZED TO ONE SOURCE PARTICLE)

		ENERGY (MEV)				CHARGE (ELECTRONS)			
SZONE	MAT.	PRIM	KNOCK	G-SEC	TOTAL	PRIM	KNOCK	G-SEC	TOTAL
101	7	1.807E-03 14	4.790E-05 99	2.619E-04 23	2.117E-03 13	2.800E-04 30	4.000E-05 99	-1.600E-04 76	1.600E-04 67
102	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
103	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
104	7	3.234E-03 9	1.858E-04 65	3.519E-04 23	3.772E-03 10	4.800E-04 21	1.200E-04 87	1.200E-04 87	7.200E-04 32
105	1	2.019E-02 4	2.662E-04 63	2.962E-03 8	2.342E-02 3	5.240E-03 10	3.200E-04 76	4.800E-04 46	6.040E-03 10
106	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
107	1	2.750E-02 4	1.315E-04 99	4.352E-03 10	3.198E-02 4	7.680E-03 8	2.000E-04 80	-1.600E-04 99	7.720E-03 8
108	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
109	1	1.479E-02 9	-7.755E-05 99	3.565E-03 9	1.828E-02 6	4.080E-03 13	4.000E-05 99	-1.600E-04 99	3.960E-03 12
110	8	4.576E-03 4	-1.144E-04 99	4.623E-04 12	4.923E-03 5	1.160E-03 17	-2.800E-04 60	-1.200E-04 99	7.600E-04 35
111	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
112	8	3.773E-05 29	4.729E-06 99	3.348E-06 99	4.581E-05 19	4.000E-05 99	0.000E+00 99	0.000E+00 99	4.000E-05 99
113	8	6.428E-05 29	0.000E+00 99	7.323E-06 99	7.160E-05 29	4.000E-05 99	0.000E+00 99	0.000E+00 99	4.000E-05 99
114	8	5.250E-05 39	0.000E+00 99	4.626E-06 99	5.713E-05 42	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
115	8	5.994E-05 27	0.000E+00 99	2.797E-06 99	6.274E-05 28	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
116	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
117	5	1.331E-02 5	4.703E-05 99	1.359E-03 13	1.471E-02 6	3.280E-03 9	4.000E-05 99	1.600E-04 99	3.480E-03 16
118	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
119	8	1.872E-05 57	0.000E+00 99	0.000E+00 99	1.872E-05 57	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
120	8	2.318E-05 45	0.000E+00 99	0.000E+00 99	2.318E-05 45	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
121	8	5.291E-05 86	0.000E+00 99	0.000E+00 99	5.291E-05 86	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
122	8	2.947E-06 99	0.000E+00 99	2.509E-06 99	5.456E-06 67	4.000E-05 99	0.000E+00 99	0.000E+00 99	4.000E-05 99
123	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
124	1	1.175E-02 8	1.849E-04 53	2.946E-03 10	1.488E-02 8	3.920E-03 8	2.000E-04 86	-2.800E-04 99	3.840E-03 9
125	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
126	8	2.001E-06 99	0.000E+00 99	0.000E+00 99	2.001E-06 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
127	8	7.397E-06 52	0.000E+00 99	0.000E+00 99	7.397E-06 52	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99

128	8	1.121E-05 51	0.000E+00 99	0.000E+00 99	1.121E-05 51	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
129	8	5.111E-06 99	0.000E+00 99	1.378E-06 99	6.489E-06 79	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
130	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
131	1	4.445E-03 10	8.154E-05 99	1.382E-03 13	5.909E-03 8	1.200E-03 19	2.000E-04 68	-3.200E-04 58	1.080E-03 25
132	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
133	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
134	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
135	8	4.071E-06 69	0.000E+00 99	0.000E+00 99	4.071E-06 69	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
136	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
137	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
138	7	2.320E-03 11	6.391E-05 71	5.399E-04 20	2.924E-03 10	1.600E-04 55	1.600E-04 55	-1.200E-04 51	2.000E-04 68
139	8	1.930E-03 6	-3.412E-05 99	5.201E-04 14	2.416E-03 5	8.800E-04 24	-8.000E-05 99	4.000E-05 99	8.400E-04 40
140	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
141	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
142	8	1.804E-05 69	0.000E+00 99	0.000E+00 99	1.804E-05 69	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
143	8	1.074E-05 63	0.000E+00 99	0.000E+00 99	1.074E-05 63	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
144	8	9.708E-06 68	0.000E+00 99	0.000E+00 99	9.708E-06 68	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
145	9	4.438E-03 5	-4.266E-05 99	4.213E-04 24	4.817E-03 5	4.000E-04 26	-1.600E-04 85	4.000E-05 99	2.800E-04 88
146	9	1.331E-03 10	1.035E-04 48	3.486E-04 32	1.783E-03 11	3.600E-04 42	1.200E-04 51	8.000E-05 99	5.600E-04 45
147	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
148	7	1.542E-03 19	-4.342E-05 99	2.401E-04 21	1.739E-03 16	1.200E-04 51	-4.000E-05 99	-2.000E-04 54	-1.200E-04 99
149	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
150	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99

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ENERGY AND CHARGE DEPOSITION
(NORMALIZED TO ONE SOURCE PARTICLE)

		ENERGY (MEV)				CHARGE (ELECTRONS)			
SZONE	MAT.	PRIM	KNOCK	G-SEC	TOTAL	PRIM	KNOCK	G-SEC	TOTAL
151	7	1.585E-03 26	5.421E-06 99	3.346E-04 26	1.925E-03 25	1.600E-04 55	0.000E+00 99	8.000E-05 99	2.400E-04 57
152	1	4.749E-03 10	-9.285E-05 47	1.479E-03 14	6.135E-03 8	1.040E-03 14	-1.600E-04 41	-8.000E-05 99	8.000E-04 24
153	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
154	1	7.199E-03 12	8.838E-05 65	1.827E-03 8	9.114E-03 10	1.480E-03 13	1.600E-04 55	-1.200E-04 99	1.520E-03 20
155	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
156	1	5.800E-03 11	-6.656E-05 99	2.272E-03 7	8.005E-03 7	1.480E-03 13	-8.000E-05 99	4.000E-05 99	1.440E-03 15
157	8	2.154E-03 10	2.254E-05 99	3.003E-04 19	2.477E-03 9	4.400E-04 25	-8.000E-05 67	-1.600E-04 76	2.000E-04 61
158	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
159	8	2.723E-05 63	0.000E+00 99	0.000E+00 99	2.723E-05 63	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
160	8	1.643E-05 47	0.000E+00 99	2.787E-07 99	1.671E-05 46	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
161	8	2.051E-05 53	0.000E+00 99	1.169E-05 69	3.220E-05 50	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
162	8	4.816E-05 33	0.000E+00 99	5.632E-07 99	4.872E-05 34	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
163	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
164	4	4.335E-04 24	5.392E-05 56	1.030E-03 15	1.518E-03 9	1.600E-04 41	8.000E-05 99	-4.000E-05 99	2.000E-04 99
165	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
166	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
167	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
168	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
169	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
170	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
171	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
172	5	5.848E-03 3	-1.248E-05 99	1.024E-03 9	6.860E-03 3	1.480E-03 16	4.000E-05 99	2.000E-04 99	1.720E-03 22

173	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
174	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
175	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
176	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
177	8	8.365E-08	99	0.000E+00	99	0.000E+00	99	8.365E-08	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
178	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
179	4	8.155E-04	22	4.168E-06	99	6.538E-04	9	1.473E-03	10	2.400E-04	44	8.000E-05	99	-3.200E-04	45	1.626E-20	99
180	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
181	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
182	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
183	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
184	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
185	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
186	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
187	8	4.790E-03	4	-4.759E-07	99	6.853E-04	11	5.474E-03	4	1.440E-03	9	0.000E+00	99	8.000E-05	99	1.520E-03	17
188	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
189	8	0.000E+00	99	0.000E+00	99	1.639E-06	99	1.639E-06	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
190	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
191	8	0.000E+00	99	0.000E+00	99	2.091E-06	99	2.091E-06	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
192	8	0.000E+00	99	0.000E+00	99	1.601E-06	99	1.601E-06	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
193	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
194	8	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
195	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
196	8	5.449E-03	13	6.392E-05	99	1.540E-03	11	7.054E-03	11	1.840E-03	15	1.200E-04	99	8.000E-05	99	2.040E-03	14
197	8	4.738E-03	11	1.371E-04	38	1.797E-03	11	6.673E-03	10	1.760E-03	14	2.400E-04	37	1.600E-04	99	2.160E-03	14
198	8	6.684E-03	10	9.946E-05	51	1.252E-03	18	8.035E-03	10	2.080E-03	17	1.200E-04	71	2.800E-04	60	2.480E-03	15
199	8	6.474E-03	11	7.712E-05	99	1.659E-03	9	8.211E-03	9	2.280E-03	16	1.200E-04	99	4.000E-05	99	2.440E-03	12
200	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99

1

ENERGY AND CHARGE DEPOSITION
(NORMALIZED TO ONE SOURCE PARTICLE)

		ENERGY(MEV)								CHARGE(ELECTRONS)							
SZONE	MAT.	PRIM		KNOCK		G-SEC		TOTAL		PRIM		KNOCK		G-SEC		TOTAL	
201	8	5.249E-04	10	2.677E-05	70	1.559E-04	28	7.076E-04	10	1.600E-04	41	0.000E+00	99	8.000E-05	67	2.400E-04	37
202	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
203	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
204	10	5.072E-02	5	-2.199E-05	99	2.899E-02	4	7.968E-02	3	1.100E-02	4	6.099E-21	99	-6.000E-04	81	1.040E-02	5
205	10	2.903E+00	1	9.093E-03	12	1.846E-01	2	3.097E+00	1	3.835E-01	1	8.720E-03	13	-1.720E-03	36	3.905E-01	1
206	2	8.661E-01	1	-3.455E-02	5	5.955E-03	5	8.375E-01	1	2.076E-02	6	-2.276E-02	5	-3.200E-04	74	-2.320E-03	75
207	2	5.534E-04	35	-2.633E-08	99	1.601E-02	8	1.656E-02	8	3.200E-04	36	0.000E+00	99	6.800E-04	35	1.000E-03	25
208	2	1.705E-02	8	3.630E-04	46	4.661E-03	7	2.207E-02	7	3.360E-03	10	3.200E-04	45	3.600E-04	56	4.040E-03	11
209	2	4.701E-03	13	1.043E-04	43	1.203E-03	14	6.008E-03	13	1.160E-03	22	1.600E-04	67	2.400E-04	79	1.560E-03	28
210	2	1.790E-02	8	1.443E-04	86	4.281E-03	5	2.233E-02	6	3.800E-03	11	1.200E-04	99	-4.000E-05	99	3.880E-03	12
211	2	4.793E-03	9	6.818E-05	99	8.017E-04	17	5.663E-03	7	1.480E-03	17	4.000E-05	99	2.000E-04	99	1.720E-03	21
212	0	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99	0.000E+00	99
213	5	1.935E-02	7	3.320E-04	47	7.731E-03	5	2.741E-02	6	4.480E-03	9	2.000E-04	99	-3.600E-04	99	4.320E-03	18
214	5	8.334E-03	6	-3.922E-06	99	7.837E-03	6	1.617E-02	3	1.920E-03	11	-4.000E-05	99	5.200E-04	70	2.400E-03	22
215	5	4.686E-03	9	-3.944E-05	99	6.085E-03	9	1.073E-02	4	1.440E-03	13	-1.200E-04	87	-5.600E-04	68	7.600E-04	68
216	5	2.915E-03	10	5.981E-05	58	5.909E-03	11	8.885E-03	6	1.240E-03	14	1.600E-04	55	-2.400E-04	99	1.160E-03	41
217	5	1.605E-03	14	-1.811E-05	99	4.707E-03	10	6.293E-03	9	7.600E-04	28	-4.000E-05	99	-2.000E-04	99	5.200E-04	88

218	5	5.432E-04 44	1.811E-05 99	3.730E-03 6	4.292E-03 9	2.800E-04 37	4.000E-05 99	-7.200E-04 63	-4.000E-04 99
219	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
220	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
221	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
222	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
223	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
224	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
225	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
226	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
227	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
228	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
229	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
230	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
231	0	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
232	6	8.162E-04 20	1.939E-05 99	4.775E-04 28	1.313E-03 12	2.800E-04 30	4.000E-05 99	0.000E+00 99	3.200E-04 41
233	6	2.323E-04 54	0.000E+00 99	1.364E-04 50	3.687E-04 32	4.000E-05 99	0.000E+00 99	4.000E-05 99	8.000E-05 67
234	6	6.987E-05 99	1.869E-06 99	3.813E-05 94	1.099E-04 68	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
235	6	1.618E-04 54	0.000E+00 99	6.748E-05 51	2.293E-04 38	8.000E-05 67	0.000E+00 99	0.000E+00 99	8.000E-05 67
236	8	1.260E-05 99	0.000E+00 99	1.201E-05 84	2.461E-05 61	0.000E+00 99	0.000E+00 99	4.000E-05 99	4.000E-05 99
237	8	1.083E-05 99	0.000E+00 99	1.448E-06 91	1.227E-05 88	0.000E+00 99	0.000E+00 99	-4.000E-05 99	-4.000E-05 99
238	8	0.000E+00 99	0.000E+00 99	4.187E-05 69	4.187E-05 69	0.000E+00 99	0.000E+00 99	4.000E-05 99	4.000E-05 99
239	8	0.000E+00 99	0.000E+00 99	1.042E-04 71	1.042E-04 71	0.000E+00 99	0.000E+00 99	-8.000E-05 67	-8.000E-05 67
240	8	0.000E+00 99	0.000E+00 99	1.454E-05 78	1.454E-05 78	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
241	8	0.000E+00 99	0.000E+00 99	6.477E-05 52	6.477E-05 52	0.000E+00 99	0.000E+00 99	-4.000E-05 99	-4.000E-05 99
242	8	2.694E-05 99	7.734E-06 99	0.000E+00 99	3.468E-05 78	0.000E+00 99	4.000E-05 99	0.000E+00 99	4.000E-05 99
243	8	2.100E-06 99	0.000E+00 99	1.107E-05 89	1.317E-05 77	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
244	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
245	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
246	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
247	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
248	8	0.000E+00 99	0.000E+00 99	5.119E-06 99	5.119E-06 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
249	8	0.000E+00 99	0.000E+00 99	5.444E-07 99	5.444E-07 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
250	8	9.843E-06 67	0.000E+00 99	0.000E+00 99	9.843E-06 67	4.000E-05 99	0.000E+00 99	0.000E+00 99	4.000E-05 99

1

ENERGY AND CHARGE DEPOSITION
(NORMALIZED TO ONE SOURCE PARTICLE)

		ENERGY (MEV)				CHARGE (ELECTRONS)			
SZONE	MAT.	PRIM	KNOCK	G-SEC	TOTAL	PRIM	KNOCK	G-SEC	TOTAL
251	8	8.357E-06 99	0.000E+00 99	0.000E+00 99	8.357E-06 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
252	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
253	8	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
254	8	3.183E-05 73	0.000E+00 99	1.299E-07 99	3.196E-05 73	4.000E-05 99	0.000E+00 99	0.000E+00 99	4.000E-05 99
255	8	0.000E+00 99	0.000E+00 99	4.182E-06 99	4.182E-06 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
256	8	0.000E+00 99	1.763E-05 99	0.000E+00 99	1.763E-05 99	0.000E+00 99	4.000E-05 99	0.000E+00 99	4.000E-05 99
257	8	4.644E-05 99	0.000E+00 99	0.000E+00 99	4.644E-05 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
258	8	4.721E-05 99	0.000E+00 99	0.000E+00 99	4.721E-05 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
259	8	0.000E+00 99	0.000E+00 99	3.458E-06 99	3.458E-06 99	0.000E+00 99	0.000E+00 99	0.000E+00 99	0.000E+00 99
0 TOTAL		8.292E+00 0	-1.792E-02 4	4.512E-01 1	8.725E+00 0	9.400E-01 0	-5.640E-03 10	-6.200E-03 6	9.281E-01 0

0 THE ENERGY CONSERVATION FRACTION IS .9991906360461E+00 0

Appendix 8
CYLTRAN Input File for 6.0 MeV Electron Beam Disk Source Normally Incident on the CEASE Telescope Top Surface

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TITLE
  6.0 MEV CEASE CYLTRAN TEST FRONT ENTRY, NORMAL INCIDENCE
********************** GEOMETRY **********************
GEOMETRY 126
  0.0       0.02540  0.0      0.53340   0
  0.02540   0.05080  0.0      0.50800   0
  0.05080   0.07620  0.0      0.48260   0
  0.07620   0.10160  0.0      0.45720   0
  0.10160   0.12700  0.0      0.43180   0
  0.12700   0.15240  0.0      0.40640   0
  0.15240   0.17780  0.0      0.38100   0
  0.17780   0.20320  0.0      0.35560   0
  0.20320   0.22860  0.0      0.33020   0
  0.22860   0.25400  0.0      0.30480   0
  0.25400   0.27940  0.0      0.27940   0
  0.27940   0.30480  0.0      0.25400   0
  0.30480   0.33020  0.0      0.22860   0
  0.33020   0.35560  0.0      0.20320   0
  0.35560   0.38100  0.0      0.17780   0
  0.38100   0.40640  0.0      0.15240   0
  0.40640   0.43180  0.0      0.12700   0
  0.43180   0.45720  0.0      0.10160   0
*19
  0.0       0.02540  0.53340  0.750711   10
  0.02540   0.05080  0.50800  0.750711   10
  0.05080   0.07620  0.48260  0.750711   10
  0.07620   0.10160  0.45720  0.750711   10
  0.10160   0.12700  0.43180  0.750711   10
  0.12700   0.15240  0.40640  0.750711   10
  0.15240   0.17780  0.38100  0.750711   10
  0.17780   0.20320  0.35560  0.750711   10
  0.20320   0.22860  0.33020  0.750711   10
  0.22860   0.25400  0.30480  0.750711   10
  0.25400   0.27940  0.27940  0.750711   10
  0.27940   0.30480  0.25400  0.750711   10
  0.30480   0.33020  0.22860  0.750711   10
  0.33020   0.35560  0.20320  0.750711   10
  0.35560   0.38100  0.17780  0.750711   10
  0.38100   0.40640  0.15240  0.750711   10
  0.40640   0.43180  0.12700  0.750711   10
  0.43180   0.45720  0.10160  0.750711   10
*37
  0.45720   0.45810  0.41910  0.750711   10
  0.45810   0.50800  0.41910  0.750711   10
  0.45720   0.45810  0.0      0.419100    2
  0.45810   0.50800  0.02286  0.41910     3
*41
  0.45810   0.50800  0.0      0.02286     0
  0.0       0.35560  0.750711 1.06680    10
  0.35560   0.50800  0.750711 1.06680     0
*44-47  PMMA RODS NEGLECTED
*48-55  STAINLESS BOLTS NEGLECTED
*56
  0.50800   0.51652  0.0      0.31110     0
  0.50800   0.51652  0.31110  0.41910     4
  0.50800   0.51652  0.41910  1.027288    0
*59-62 PMMA RODS NEGLECTED
*63
  0.51652   0.56732  0.0      0.31110     0
*64-67 PMMA RODS NEGLECTED
*68
  0.51652   0.56732  0.31110  1.001777     5
  0.51652   0.56732  1.001777 1.027288     0
*70 APPROXIMATE TRUNCATED CONE WITH CYLINDER
  0.56732   0.592208 0.0      0.29866     0
  0.56732   0.592208 0.29866  0.80000     1
  0.56732   0.592208 0.80000  1.027288    0
*73-76 PMMA RODS NEGLECTED
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  0.51652  0.56732  1.001777  1.027288     0
*70 APPROXIMATE TRUNCATED CONE WITH CYLINDER
  0.56732  0.592208 0.0       0.29866     0
  0.56732  0.592208 0.29866   0.80000     1
  0.56732  0.592208 0.80000   1.027288    0
*73-76 PMMA RODS NEGLECTED
*77
  0.592208 0.64199  0.0       0.28622     0
  0.592208 0.64199  0.28622   0.80000     1
  0.592208 0.64199  0.80000   1.027288    0
*80-83 PMMA RODS NEGLECTED
*84
  0.64199  0.704212 0.0       0.28622     0
  0.64199  0.704212 0.28622   0.34844     7
  0.64199  0.704212 0.34844   0.80000     8
  0.64199  0.704212 0.80000   1.027288    0
*88-91 PMMA RODS NEGLECTED
*92
  0.704212 0.719212 0.0       0.40210     9
  0.704212 0.719212 0.40210   0.73422     9
  0.704212 0.719212 0.73422   0.80000     8
  0.704212 0.719212 0.80000   1.027288    0
*96-99 PMMA RODS NEGLECTED
*100
  0.719212 0.744212 0.0       0.28622     0
  0.719212 0.744212 0.28622   0.34844     7
  0.719212 0.744212 0.34844   0.73422     0
  0.719212 0.918323 0.73422   0.80000     8
  0.719212 0.918323 0.80000   1.027288    0
*105-108 PMMA RODS NEGLECTED
*109
  0.744212 0.787657 0.0       0.28622     0
  0.744212 0.787657 0.28622   0.34844     7
  0.744212 0.787657 0.34844   0.73422     1
  0.787657 0.856101 0.0       0.28622     0
  0.787657 0.856101 0.28622   0.73422     1
*114  APPROXIMATE TRUNCATED CONE WITH CYLINDER
  0.856101 0.918323 0.0       0.31733     0
  0.856101 0.918323 0.31733   0.73422     1
  0.918323 0.969123 0.0       0.423111    0
  0.918323 0.969123 0.423111  1.001777    5
  0.918323 0.969123 1.001777  1.027288    0
*119-122 PMMA RODS NEGLECTED
*123 APPROXIMATE TRUNCATED CONE WITH CYLINDER
  0.969123 1.019123 0.        0.398111    0
  0.969123 1.019123 0.398111  0.80000     1
  0.969123 1.019123 0.80000   1.027288    0
*126-129 PMMA RODS NEGLECTED
*130
  1.019123 1.043789 0.        0.373111    0
  1.019123 1.043789 0.373111  0.80000     1
  1.019123 1.043789 0.80000   1.027288    0
*133-136 PMMA RODS NEGLECTED
*137
  1.043789 1.113477 0.        0.373111    0
  1.043789 1.113477 0.373111  0.43533     7
  1.043789 1.113477 0.43533   0.80000     8
  1.043789 1.113477 0.80000   1.027288    0
*141-144 PMMA RODS NEGLECTED
*145
  1.113477 1.163477 0.0       0.518942    9
  1.113477 1.163477 0.518942  0.73422     9
  1.163477 1.203477 0.0       0.373111    0
  1.163477 1.203477 0.373111  0.43533     7
  1.163477 1.203477 0.43533   0.73422     0
  1.203477 1.243477 0.        0.373111    0
  1.203477 1.243477 0.373111  0.43533     7
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  1.203477 1.243477 0.43533   0.73422     1
  1.243477 1.293477 0.        0.373111    0
  1.243477 1.293477 0.373111  0.73422     1
*155 APPROXIMATE TRUNCATED CONE WITH CYLINDER
  1.293477 1.352774 0.        0.404221    0
  1.293477 1.352774 0.404221  0.73422     1
  1.113477 1.352774 0.73422   0.80000     8
  1.113477 1.352774 0.80000   1.027288    0
*159-162 PMMA RODS NEGLECTED
*163
  1.352774 1.360394 0.        0.4064      0
  1.352774 1.360394 0.4064    0.6096      4
  1.352774 1.360394 0.6096    1.001777    0
  1.352774 1.360394 1.001777  1.027288    0
*167-170 PMMA RODS NEGLECTED
*171
  1.360394 1.41119  0.        0.4064      0
  1.360394 1.41119  0.4064    1.001777    5
  1.360394 1.41119  1.001777  1.027288    0
*174-177 PMMA RODS NEGLECTED
*178
  1.41119 1.418810  0.        0.4064      0
  1.41119 1.418810  0.4064    0.6096      4
  1.41119 1.418810  0.6096    1.001777    0
  1.41119 1.418810  1.001777  1.027288    0
*182-185 PMMA RODS NEGLECTED
*186
  1.41881 1.518365  0.        0.5080      0
  1.41881 1.518365  0.5080    1.001777    8
  1.41881 1.518365  1.001777  1.027288    0
*189-192 PMMA RODS NEGLECTED
*193
  1.518365 1.953921 0.        0.5080      0
  1.518365 1.953921 0.5080    1.001777    8
  1.518365 1.953921 1.001777  1.027288    0
*196-199 PMMA RODS NEGLECTED
*200
  1.953921 1.971965 0.        0.5080      0
  1.953921 1.971965 0.5080    1.001777    8
  1.953521 1.971965 1.001777  1.027288    0
  1.971965 2.046631 0.        1.027288    0
  2.046631 2.295520 0.        1.5420      10
  0.0      0.50800  1.06680   1.5420      10
  0.50800  2.046631 1.027288  1.5420      10
********************** SOURCE ********************
ELECTRONS
ENERGY 6.0
POSITION 0.0 0.0 0.02
  RADIUS 1.4
* DEFAULT DIRECTION
     DIRECTION  0.0 0.0
*********************  OPTIONS  *******************
HISTORIES 25000
```